THE IMPORTANCE OF GESTATIONAL WEIGHT GAIN AND PSYCHOSOCIAL FACTORS TO POSTPARTUM CHANGES IN MATERNAL BODY WEIGHT, AND APPLICATIONS OF PROSPECT THEORY TO UNDERSTANDING WOMEN'S CONCEPTUALIZATION OF WEIGHT CHANGE

A Dissertation

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

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May 2010

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Cornell University 2010

This research sought to examine the contribution of pregnancy and psychosocial factors to weight change in women of reproductive age using two approaches. The first involved analysis of data from a prospective cohort study of women who were followed from pregnancy until 2 years postpartum. From these data, the natural history of weight change between one and two years postpartum was examined, and the associations of this weight change with prenatal self-efficacy and locus of control, and postpartum dietary and physical activity variables were explored. The second approach used a survey designed to test the potential applications of Prospect Theory to individuals' conceptualization of weight change in a sample of adult women. The results from the cohort study indicated that average late postpartum weight change was approximately zero, but with considerable variation, with more than half of the sample gaining weight in this period. One-year weight retention was inversely related to later weight change, and to risk of later weight gain. Prenatal self-efficacy and locus of control were positively associated with fruit and vegetable intake and exercise frequency at two years postpartum. Self-

efficacy was inversely associated with weight retention at 1 year postpartum, which was in turn inversely related to later weight change and the likelihood of returning to early pregnancy body weight. There was a positive association between prenatal self-efficacy and likelihood of returning to early pregnancy body weight. Results from the survey examining Prospect Theory showed that ratings of importance and likelihood of changing behaviors to prevent weight gain above 5 lb were higher, and difficulty ratings were lower, than those for producing weight loss above 5 lb, although importance and likelihood ratings for preventing 2 – 5 lb of weight gain were lower than those for producing 2 – 5 lb of weight loss. Importance and difficulty ratings were associated with current body size and likelihood of changing behaviors to produce weight change. Overall, these findings suggest the importance of increased attention to advocating the prevention of weight gain, especially among individuals who are currently at a healthy body weight, to prevent obesity development in women of reproductive age.

BIOGRAPHICAL SKETCH

Leah Morgan Lipsky received her B.A. in economics and music from Oberlin College in Oberlin, OH in 2000, with honors distinction in economics. She later received her M.H.S. in international health from the Johns Hopkins Bloomberg School of Public Health in Baltimore, MD in 2007, where she studied in the human nutrition program. While attending Johns Hopkins, she worked with Dr. Larwence Cheskin in the Center for Human Nutrition on a study of the effect of energy density on energy intake in adults. She began the Ph.D. program in nutrition at Cornell University in the fall of 2007. Her interest in the determinants of obesity lead her to work with Christine Olson to study the role of gestational weight gain on maternal body weight, which became the basis for her dissertation research topic.

This work is dedicated to Michael and Bennie, for whom I am infinitely grateful and who I will always strive to deserve.

ACKNOWLEDGMENTS

My deepest appreciation to the Cornell University Graduate Field of Nutrition for providing me with the opportunity to pursue graduate research at this institution, and to the members of my Special Committee for their support of my graduate studies and dissertation research. I am indebted to Kathleen Rasmussen, whose engaging course in Topics in Maternal and Child Nutrition piqued my interest in maternal obesity. I am also grateful to Jeffery Sobal, whose fascinating course in Social Science Theories in Nutrition inspired me to apply my background in economics to my doctoral research project, and to David Just for his insights in behavioral economics that enabled me to carry out this idea.

I could not have conducted this research without the help of Myla Strawderman, whose patience in delivering and explaining data to me is to be revered. I also wish to thank the other members of Christine Olson's research group for their feedback throughout my various research projects at Cornell.

I would especially like to thank my Special Committee Chairperson, Christine Olson, for her supportive mentorship throughout my doctoral program. I will always appreciate her thoughtful critiques of my work, and her insightful guidance regarding all aspects of my life at Cornell and beyond.

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LIST OF ABBREVIATIONS

1YPP……………………………………………………………..….1 year postpartum

1YWR……………………………………………………..1 year weight retention

2YPP……………………………………………………………..2 years postpartum

2YWR……………………………………………………..2 year weight retention

BMI……………………………………………………………….body mass index

BWRP………………………………………………body weight reference point

CBW………………………………...………………………current body weight

CFI…………………………………………………………comparative fit index

DBW……………………………………………………………desired body weight

EPW……………………………………………………early pregnancy weight

EXFREQ……………………………………………………exercise frequency

FV…………………………………………………fruit and vegetable intake

GWG……………………………………………………...gestational weight gain

IOM……………………………………………………………Institute of Medicine

LOC…………………………………………………………...locus of control

LPW………………………………………………...…last pregnancy weight

LPWC…………………………………………late postpartum weight change

LPWG…………………………………………….late postpartum weight gain

NW……………………………………………………………...normal weight

OB………………………………………………………………..…obese

OW…………………………………………………………………overweight

PPWR…………………………………………….postpartum weight retention

RMSEA………………………….……root mean square error of approximation

R.R……………………………………………………………..….relative risk

SD……………………………………………………………….standard deviation

SE…………………………………………………………………………self-efficacy

SE……………………………………………………………………standard error

TLI…………………………………………………..……………Tucker-Lewis index

CHAPTER 1

INTRODUCTION

The high prevalence of obesity and overweight in adults in the United States (1, 2) continues to be a public health concern due to their impact on morbidity and mortality (3). The factors contributing to the development of obesity are not well understood. This research examined the influence of pregnancy and psychosocial factors to various aspects of obesity in women.

Pregnancy has been identified as a possible risk factor for the development of obesity in women, for whom pregnancy is a natural cause of weight gain that may lead to long-term increases in BMI (4-9). In addition, pregnancy- and non-pregnancy-related weight gain in women are related to psychosocial factors. Self-efficacy (SE) and locus of control (LOC) are two such psychosocial constructs that have been studied in research on health behaviors and weight change. Measures of SE, a psychosocial construct referring to an individual's belief in her ability to use a behavior to achieve a desired goal (10), are associated with attrition from weight-control interventions as well as with outcomes associated with such treatments (11-13). SE measured prenatally has also been associated with early pregnancy BMI and dietary and exercise behaviors (14-16). In addition, LOC, a similar construct to SE, referring to an individual's belief in whether her behaviors and outcomes are internal or external to her control (17, 18), are related to performance of weight-related behaviors (19).

The work of behavioral economists offers some insights into the psychosocial constructs coming from research of the behavioral aspects of weight control. In behavioral economics, health is regarded as a commodity that results from an individual's choice of how best to allocate limited available resources such as time, effort and money (20-22). The economic concept of Prospect Theory makes specific predictions regarding an individual's subjective valuation of outcomes according to the individual's reference point (a term referring to the individual's status quo) (23). Predictions of Prospect Theory may enhance the understanding of individuals' conceptualization of weight change, and improve the delivery of health behavior interventions.

This research addressed three overarching aims. The first aim was to examine the contribution of gestational weight gain (GWG) to obesity risk in women who were followed from pregnancy until 2 years postpartum (2YPP). The second aim was to investigate how SE and LOC measured prenatally are related to health behaviors at 2YPP and weight change between 1YPP and 2YPP. The third aim was to examine potential applications of Prospect Theory to women's conceptualization of weight change. The following sections discuss the evidence for the roles of pregnancy and psychosocial factors in maternal weight change, and the potential contribution of concepts from Prospect Theory to understanding weight change in women of reproductive age.

Evidence about the relationship between pregnancy and weight retention/obesity risk

The question of how GWG is related to long-term maternal obesity risk has been studied extensively. A recent review of the literature showed consistent evidence that GWG, especially in excess of the Institute of Medicine (IOM) guidelines (4), is positively associated with postpartum weight retention (PPWR) (4). Such a relationship is expected to occur due partially to the part-whole relationship between GWG and PPWR (24). That is, weight cannot be retained unless it was gained. However, the question of whether, and to what degree excess maternal weight gained during pregnancy can be lost after delivery will help to determine the contribution of pregnancy-associated weight gain to the development of maternal obesity. Evidence regarding the relationship between GWG and PPWR suggests that some women who gain excessive amounts of weight during pregnancy may have difficulty returning to their pre-pregnancy body weight after delivery. Concerns have been raised in the literature that sustained weight retention from one pregnancy may lead to a woman being in a higher risk BMI category at the start of the next pregnancy, potentially increasing the risk of adverse maternal and fetal outcomes (4).

Previous findings have consistently suggested a positive relationship between GWG and PPWR up to 1YPP (9, 25-29). Evidence regarding body weight trajectories in the period after 1YPP is sparse. In one study that obtained several measures of body weight between delivery and 18 months postpartum, mean weight retention decreased up to 1YPP and was higher 6 months later, although there was a decreasing average within-subject pattern in body weight from 1YPP to 18 months postpartum (30). GWG was positively associated with PPWR over the study period (30). Similarly, a positive relationship between GWG and PPWR was reported in one cross-sectional study, in which women were asked at a single time point between 10 and 18 months postpartum about pre-pregnancy weight, weight at delivery, and postpartum weight (31). However, these results were based on self-reported body weight data that were assessed retrospectively, which weaken the validity of these results due both to the bias expected with self-reported body weight, and also by recall bias, which may vary with respect to body weight status or the amount of weight gained associated with pregnancy.

The relationship between GWG and maternal body weight in the very long term (5 – 15 years postpartum) has been examined in a few studies. A large proportion of a study population of obese women living in Sweden attributed their obesity to weight gain occurring during pregnancy (8, 9). In one study, weight retention 15 years after pregnancy was positively related to GWG (32). In this study, weight retention at 1YPP was a stronger predictor than GWG of weight retention at 15 years postpartum. However, there was substantial loss to follow-up (more than 75% attrition), which weakens the external validity of these results. In addition, fewer than 8% of the women in this study had BMI's above the normal weight range, suggesting that overweight is far less common in this sample than in the population of women of reproductive age living in the United States, such that the results from this research may not be generalizable to the U.S. population. Another study based in the mid-western United Statues measured weight change up to 10 years postpartum (6). The authors reported that women who had lost all pregnancy-related weight by 6 months postpartum were significantly closer to their early pregnancy body weight at follow-up compared to women who had weight retention at 6 months, with average BMI being 1.4 kg/m^2 higher in women with retention at 6 months (6). This study also had considerable attrition, which correlated significantly with several demographic and anthropometric maternal characteristics. Inasmuch as women who drop-out of such studies have reduced weight retention than women with complete data, results of studies with such long follow-up periods may overestimate average weight retention and the relationship between GWG and retention (33). The available evidence suggests a strong relationship between GWG and increased maternal body weight up to 1YPP. Due to the limited evidence regarding body weight after 1YPP, the influence of GWG on long-term maternal body weight outcomes is uncertain.

The importance of pre-pregnancy body size in postpartum weight change

Recommended guidelines for GWG vary with respect to pre-pregnancy body size, due to significant differences in the effect of GWG on optimal maternal and fetal outcomes according to pre-pregnancy body size (4). In addition, factors contributing to pre-pregnancy body weight may be reasonably expected to contribute to weight gain during pregnancy and in the postpartum period, possibly leading to a perpetual weight gain trajectory throughout these stages. Pre-pregnancy BMI may either confound or modify the relationship between GWG and PPWR in some populations. Alternatively, the relationship between pre-pregnancy BMI and PPWR may be mediated by GWG. The evidence regarding the contribution of **pre-pregnancy body size** to postpartum body weight outcomes is mixed. Some studies show a positive relationship between pre-pregnancy BMI and weight retention and weight change (25, 34-36), while others have reported no association (6, 28, 32, 37, 38), and the results of one study showed an inverse relationship between pre-pregnancy BMI and weight change up to 9 months postpartum (27). One methodological problem contributing to these conflicting results is that GWG is often calculated from self-reported pre-pregnancy body weight (and more rarely from self-reported weight at delivery), which is subject to bias that increases with BMI (24). Despite high correlations between self-reported and measured body weight (39), small errors in body weight measures can contribute to large discrepancies in the calculation of GWG and PPWR (24). Consequently, GWG and PPWR are more likely to be overestimated in overweight and obese women than normal weight women if they are calculated from self-reported measures of body weight. Nevertheless, pre-pregnancy BMI is of concern in studies of GWG and PPWR in light of the high prevalence of overweight and obesity in women of reproductive age in the United States, and the adverse maternal and fetal outcomes associated with elevated pre-pregnancy BMI (4). The issue of greatest public health concern is whether women with high pre-pregnancy BMI have elevated risk of continued increases in BMI as a result of GWG relative to women with normal pre-pregnancy BMI, which would represent a cumulative, “snow-ball” effect on long-term maternal obesity risk.

Health behaviors and socioeconomic correlates to postpartum weight change

Previous researchers have explored the importance of **health behaviors** and **socioeconomic characteristics** to postpartum weight change. The evidence regarding the impact of eating and exercise behaviors on postpartum weight change is mixed, with some studies showing significant associations (6, 25, 40-42), and others failing to show a significant relationship (37, 43). Several socioeconomic and behavioral variables, including age, race/ethnicity, income, marital status, infant feeding practices and smoking are related to GWG and PPWR (9, 24, 28, 30-32, 36, 41, 44-48), although studies are inconsistent in measuring and controlling for these variables, and results across studies are somewhat conflicting. GWG and PPWR are generally expected to be inversely related to income and smoking, and lower for married than non-married women. Greater GWG and PPWR among non-White women than White women has also been reported (4, 29, 31, 49). Additionally, breastfeeding is expected to be inversely related to PPWR (6, 30, 50), although results from studies are mixed (42, 43, 51).

Psychosocial factors

Limited research has examined the importance of **psychosocial factors** to determining postpartum health behaviors and weight change. **Self-efficacy (SE)**, a construct originating from Bandura's Social Cognitive Theory (10, 52), has been utilized often in nutrition and health behavior research. This task-specific construct, which reflects a person's confidence in her own ability to use a specific behavior in the face of challenges to achieve a desired outcome, influences choices about accepting or rejecting behavior changes

(53). Some evidence suggests that SE is positively related to improved completion and anthropometric outcomes of weight control interventions (54), and to improvements in diet and exercise behavior (55). However, other studies have reported no significant relationships between SE and weight loss outcomes (56).

In pregnant women, SE may be associated with weight control and related dietary and exercise behaviors in the prenatal and postpartum periods. SE assessed during pregnancy was strongly correlated with current intake of fruit and vegetables as well as with previous success with weight loss (14), and to predict change in exercise frequency between pregnancy and 1YPP (16). SE assessed at 1YPP was also related to exercise frequency and reduction of energy intake measured concurrently (15). However, SE was not related to GWG within the IOM guidelines (46), suggesting the strong influence of other biological and environmental factors.

Locus of control (LOC), a construct originating from Rotter's Social Learning Theory that is similar to SE, is an individual's belief regarding the orientation of control over her actions and outcomes (17, 18). A person with "internal" LOC considers her actions and the result of such actions to be within her control, whereas a person with "external" LOC considers these to be determined by external forces outside of her own control. Individuals with internal LOC are expected to be more likely to take responsibility for their actions, and engage in health behaviors to achieve a desired health outcome, than those with external LOC (53).

LOC, which is considered to be domain-specific (rather than task-specific, as is SE), is described as a construct that is an important predictor of health behavior, primarily in concert with other psychosocial constructs (53). Results from studies examining the relationship between LOC and healthy diet and exercise behaviors are mixed. Evidence from some studies suggests that internal LOC is predictive of completion of weight control interventions, and success with weight loss (54), while results from another study suggest that LOC is unrelated to healthy lifestyle behaviors (57). However, the measurement of LOC in the latter study was very general, and thus may not have captured the specific domain relevant to health behaviors. In studies of pregnant women, weight LOC is related to previous weight-loss attempts (14), pre-pregnancy BMI (58), and dietary behaviors (59). However, studies have also revealed an insignificant relationship between LOC and GWG or postpartum exercise behaviors and weight change (46, 60). The varied findings regarding the relationship between LOC and weight-related behaviors has been said to be partly due to the failure to examine LOC together with other psychosocial constructs (53).

The contribution of concepts from behavioral economics

The health behavior theories, such as those discussed above, applied in obesity research often refer to the importance of importance of individuals' outcome expectancies in influencing health behavior decisions. However, these theories do not provide a descriptive framework for understanding what these expectations are or how they develop. Recent reviews of randomized clinical trials for the treatment and prevention of obesity in adults have revealed mixed results in terms of initial or sustained effects on body weight or body fat, and a need for the development of a more comprehensive theoretical framework to assist the design of future interventions (61). Concepts from behavioral economics may help to expand the framework for understanding decisions regarding health and weight-related behaviors by providing insights into how individuals operationalize the value of expected weight outcomes. Behavioral economics considers body weight as a commodity similar to other consumption goods (clothes, chocolate, pencils, widgets, etc.) in that it is an object that has value, and that results from an individual's decisions regarding the allocation of resources given a set of constraints that will produce maximum overall well-being (20-22). Body weight, much like other health-related outcomes, is often a commodity that is consumed only in the future (versus the present). The extensive economics literature shows that such time delays affect an individual's valuation of that commodity in a negative direction. That is, because body weight is the future outcome of behavioral decisions that occur in the present, body weight is devalued (20). Studies have shown that BMI is related to measures of time preference (the degree to which outcomes are devalued as a function of time delay), whereby higher BMIs are associated with increased devaluation of outcomes as a result of time delay (62-65). Uncertainty regarding the future outcomes of present behaviors will contribute to the outcome being further devalued. From this perspective, diminished SE and LOC would be considered to reflect an increase in perceived uncertainty of, and hence, devaluation of, the outcome of present behaviors, which would contribute towards a decreased likelihood of engaging in behaviors to produce the outcome. However, uncertainty of an outcome is only one aspect of the valuation of body weight and health outcomes according to the behavioral economics framework.

Other characteristics of body weight and health commodities

From an economics perspective, weight control behaviors and outcomes are predicted to share similar properties to other commodities. One such characteristic is that body weight can be regarded as having value for the individual. In the health behavior theory research, this value, often referred to as "outcome expectancies", plays a major role in behavioral decisions (10, 17, 52, 66-68). The literature on Prospect Theory suggests that the valuations of commodities are evaluated with respect to an individual's reference point (status quo). Specifically, Prospect Theory specifies that a gain (improvement in well-being) of a given amount is valued less than a loss (decrease in well-being) of the same amount, and that a large gain or loss is valued proportionally less than a small gain or loss (23, 69, 70). It follows that whether an outcome is considered a gain or a loss will depend on the individual's reference point. In terms of body weight, weight loss may be considered to be an improvement in well-being for an overweight individual, but an individual who is underweight or at her desired body weight may consider a weight loss to be a negative outcome (one that decreases her well-being). To the author's knowledge, no studies have examined whether the predictions of Prospect Theory apply to valuation of body weight. Such information may provide insights for understanding how individuals make decisions regarding weight control behaviors, and enhance the conceptual framework for the design and delivery of behavioral interventions.

Conclusion

The overarching aim of this dissertation research was to examine the contribution of GWG, psychosocial factors, and Prospect Theory to weight change and obesity risk in adult women of reproductive age. Chapter 2 examines the relationships between GWG and weight change between 1YPP and 2YPP, and obesity risk at 2YPP. The influence of psychosocial factors on weight-related behaviors and weight trajectories during this period was also investigated (Chapter 3). Finally, applications of Prospect Theory to understanding perspectives on weight control in adult women were investigated in Chapter 4. An overview and conclusions of the findings are presented in Chapter 5. Findings of this research may contribute towards a better understanding of the contribution of GWG to maternal obesity risk, and of the theoretical framework underlying the behavioral decisions leading to the development of obesity in women of reproductive age.

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CHAPTER 2

MATERNAL BODY WEIGHT OUTCOMES BETWEEN 1 AND 2 YEARS POSTPARTUM IN RELATION TO EARLY PREGNANCY BODY MASS INDEX, GESTATIONAL WEIGHT GAIN AND 1-YEAR WEIGHT RETENTION

Abstract

The contribution of gestational weight gain (GWG) to maternal obesity is not fully understood. In particular, little is known about the natural history of maternal weight after 1 year postpartum (1YPP). The aim of this study was to examine late postpartum weight change (LPWC, between 1YPP and 2 years postpartum (2YPP)), and its associations with early pregnancy body size, GWG and 1 year weight retention (1YWR). Methods involved analysis of data from a prospective observational cohort study of 413 women in upstate New York, U.S.A. Average LPWC was approximately zero, although more than half the sample gained weight between 1 and 2 years postpartum. LPWC was inversely related to 1YWR ($p < 0.001$). GWG was unrelated to LPWC in models adjusted for 1YWR. Women with major weight retention at 1YPP were unlikely to return to early pregnancy body weight (EPW) by 2YPP. Only 35 (8.5%) women moved to a higher risk BMI category between early pregnancy and 2YPP. These results suggest that 1YWR mediates the relationship between GWG and LPWC. The high frequency of weight gain after 1YPP suggests that women who return to EPW in the first year postpartum should be alerted to the tendency for many such women to gain weight. In addition, these results indicate the importance of accounting for postpartum weight gain

in order to prevent biased estimation of the influence of GWG on long-term increases in maternal body weight.

Introduction

Pregnancy has been identified as a period of risk for excessive weight gain, potentially leading to long-term weight retention and obesity in women (1-7). GWG, particularly in excess of the IOM recommendations, is related to increased postpartum weight retention (7-13), suggesting that women who gain weight excessively during pregnancy may be at risk for long-term increases in BMI (6, 14-16). In addition, women with high BMI prior to pregnancy may be predisposed to excess gestational weight gain (GWG) (17), and may have elevated risk of postpartum weight retention(18) and weight gain (19). Indeed, both high pre-pregnancy BMI and excessive GWG are reasonably suspected to be indicators of general susceptibility to weight gain, suggesting a subgroup of women who may have elevated obesity risk resulting from pregnancy. However, little is known about the natural history of body weight in the postpartum period after the initial 12 months, and the influence of pre-pregnancy BMI and GWG on weight change during this period is not fully understood. In particular, little attention has been given to the potential for postpartum weight gain, which, if unaccounted for, may be misclassified as retention of GWG (20-21).

The aims of this paper are to describe the natural history of maternal body weight occurring between 1YPP and 2 years postpartum (2YPP), and to examine its associations with early pregnancy BMI, GWG, and weight retention at 1 year postpartum (1YWR), using the conceptual framework illustrated in **Figure 2.1**. Early pregnancy BMI, GWG and 1YWR were hypothesized to by positively related to late postpartum weight change and increased BMI. The effect of GWG and early pregnancy BMI on late postpartum weight change was hypothesized to be mediated through their effects on 1YWR. Such information will elucidate trends in postpartum body weight, and contribute to the understanding of the influence of pregnancy-associated weight gain on long-term maternal obesity risk.

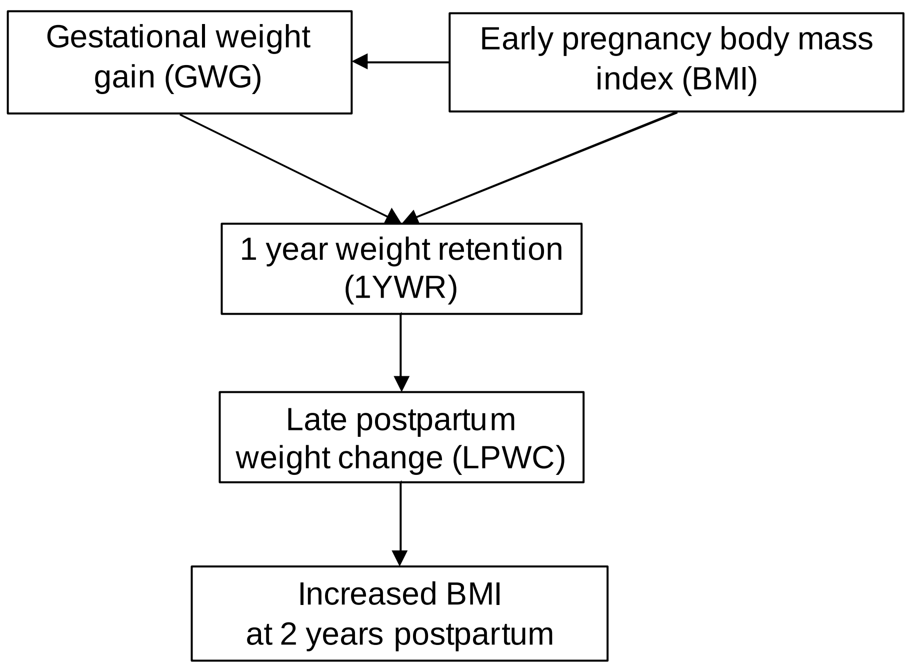

Figure 2. 1. Conceptual framework relating gestational weight gain (GWG), early pregnancy body mass index (BMI) and 1 year weight retention (1YWR) to late postpartum weight change (LPWC) between 1 and 2 years postpartum and increased maternal BMI at 2 years postpartum.

Methods

Study design and sample selection: In this prospective, longitudinal design, women were enrolled during pregnancy and followed until 2YPP. The sample included in this study is drawn from women who participated in the Bassett Mothers Health Project, a prospective cohort study of pregnant women who sought prenatal care from the Bassett Healthcare system, which spans 10 counties in upstate New York, in the U.S.A. Of the 1519 women seeking prenatal care in this geographical region during the recruitment period (March 1995 – December 1996), 1090 who met eligibility criteria for age (at least 18 years at time of delivery), no medical problems or taking medications influencing body weight, planning to keep the baby, intending to deliver within the Bassett Healthcare system, and seeking prenatal care before 28 weeks gestation were invited to participate in this study (**Figure 2.2**). Two hundred sixty-nine women actively or tacitly refused to participate (24.7%). An additional 153 women could not be located, and were presumed to have moved out of the geographical area. Twelve women did not return prenatal questionnaires. Of the 656 women who entered the study, 14 moved, 4 had fetal deaths, 13 had twin births, and 3 women were recruited again into the study with another pregnancy, leaving 622 in the original cohort. Of the original cohort, 73 women had missing 1y (n = 30) or 2y (n = 43) body weight measurements. Body weight measurements for 110 women were excluded if the 1y weight measurement was not taken within 9 – 19 months postpartum or if the 2y weight measurement was not taken within 21 – 30 months postpartum. Because the objective of this study is to make conclusions regarding the influence of GWG on postpartum body weight, data were excluded if mothers were > 14 weeks pregnant at the time of post-partum body weight measurements, or had a subsequent child born since enrollment before the 1y weight measurement or within 6 months of the 2y weight measurement[1]. The 413 women included in this study were 1.4 $\pm$ 0.5 (S.E.) years older, had 0.5 $\pm$ 0.2 years more education, were more likely to be parous (62% versus 52%, p = 0.01) and were less likely to be low income than those excluded (41% versus 50%, p = 0.03). There were no differences in the

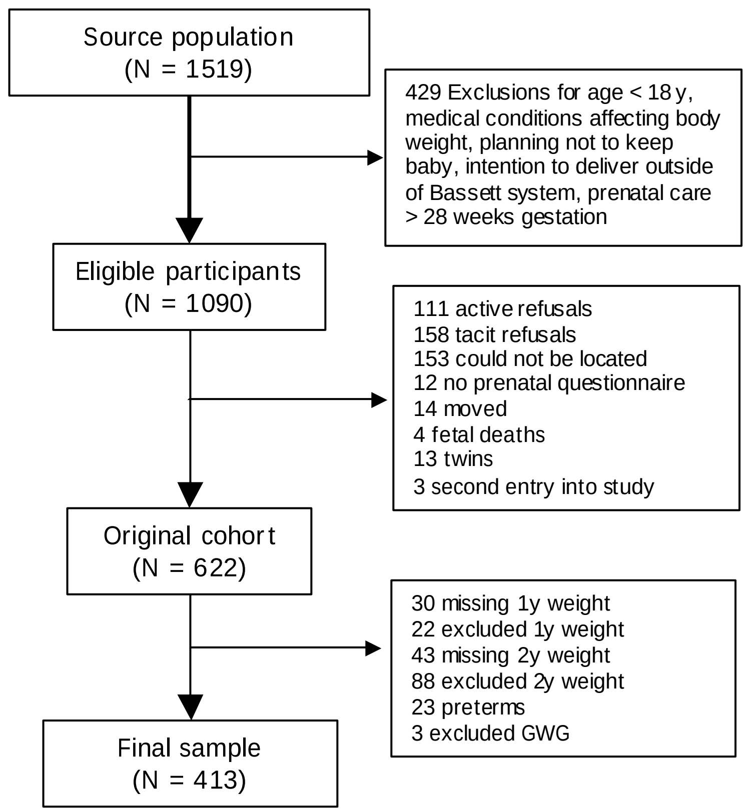

Figure 2.2. Enrollment diagram.

exposures of interest (early pregnancy BMI, GWG, 1YWR) according to study inclusion.

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[1] A variable indicating whether a woman was < 14 weeks pregnant or had a second baby more than 6 months before the 2y weight measurement was included in the models. The coefficient estimate for this variable was not statistically significant, and inclusion of this variable had no significant effect on other coefficient estimates.

Data collection and measurements: Maternal height was measured only at the first prenatal visit. Early pregnancy weight (EPW) was measured or imputed (17). For women whose first measured weights occurred after the first trimester (N = 75), EPW was imputed based on a regression model derived from the relationship between measured EPW and later measured prenatal weight in the sample of women with available corresponding prenatal body weight measurements. Although self-reported pre-pregnancy weight was also obtained for all women, this measure was not used in the analysis due to discrepancy between self-reported and measured weight that was especially marked in women with high BMI (17). Body weight was measured at regular visits to health providers before delivery, and at 1YPP and 2YPP. Study participants also completed mailed questionnaires once during the prenatal period, as well as at 1YPP and 2YPP. Study procedures were approved by the Institutional Review Boards (IRB) of Cornell University and Bassett Healthcare.

The three exposures of interest are described in **Table 2. 1**. Early pregnancy BMI was calculated from the first measured body weight and height. GWG was calculated as the difference between last measured pregnancy weight and EPW. A categorical variable was used to describe GWG according to the IOM recommendations GWG (< recommended guidelines, within guidelines, and > guidelines) (2). 1YWR is defined as the difference between body weight at 1YPP and EPW. A dichotomous variable was used to identify women with major 1YWR ($\geq$ 4.55 kg (10 lb) (18)).

Table 2.1. Definitions of body weight variables

	Variable	Definition/calculation	Categories (if applicable)
Exposures	Early pregnancy BMI (kg/m^2) (categorical)	Early pregnancy weight / height^2	BMI < 25.0 25.0 ≤ BMI < 30.0 BMI ≥ 30.0
	Gestational weight gain (categorical)	Last measured pregnancy weight – early pregnancy weight	< IOM[1] Within IOM > IOM
	Major 1YWR (binary)	1 year postpartum weight ≥ 4.55 kg + early pregnancy weight	YES NO
Outcomes	Late postpartum weight change (continuous) (kg)	Weight at 2 years postpartum– weight at 1year postpartum	--
	Late postpartum weight gain (binary)	2 years postpartum weight > 1 year postpartum weight	YES NO
	Major 2Y weight retention (binary)	1 year AND 2 year postpartum weight ≥ 4.55 kg + early pregnancy weight	YES NO
	Early pregnancy weight reached by 2 years postpartum (binary)	1 year OR 2 year postpartum weight ≤ EPW	YES NO
	Becoming overweight or obese (binary)	Becoming overweight or obese between early pregnancy and 2 years postpartum	YES NO

[1]The Institute of Medicine (IOM) guidelines specify a range for recommended gestational weight gain according to the mother's pre-pregnancy BMI category (2). The categorical variable indicates whether GWG falls within, above, or below these guidelines.

Information about covariates including age at delivery, years of education, marital status, parity and income (whether or not income was at or below 185% of the poverty income ratio (PIR)) were abstracted from medical records shortly after delivery. Data about smoking (yes/no) and infant feeding (any breastfeeding at 1YPP, yes/no) were obtained from mailed questionnaires[2].

Outcome variables: Postpartum weight retention is conventionally calculated as the difference between body weight at a given time postpartum and early or pre-pregnancy body weight (2). However, in the presence of weight gain that originates solely within the postpartum period, the conventional definition of weight retention would be a misnomer because it would include weight gain that is external to the pregnancy (21). To address this issue, several outcome variables were used to investigate the effect of early pregnancy BMI, GWG and 1YWR on late postpartum body weight (described in **Table 2.1**). **Late postpartum weight change** (LPWC) was defined as the difference between body weight at 2YPP and 1YPP. A dichotomous variable, **late postpartum weight gain** (LPWG), was also used to describe women with positive weight change between 1YPP and 2YPP. A dichotomous variable was used to describe **major late postpartum weight retention** (LPWR), which indicated whether weight retention exceeded 4.55 kg (10 lb) at both 1YPP and 2YPP (18). This variable therefore identifies women who are still carrying at least 4.55 kg of gestational weight gain at 2YPP, discerning these women from those who are 4.55 kg greater than EPW due to late postpartum weight gain (that occurring between 1YPP and 2YPP). In addition, a dichotomous variable was created to identify women who **returned to their early pregnancy**

[2] This measure of breastfeeding was determined to be the most informative in explaining the primary outcome variables. A variable was also created to indicate the number of months of breastfeeding. However, there were several missing values for this variable (n = 50), and the variable was not found to be significantly related to any of the primary outcome variables.

weight or below (EPW) at some point by 2YPP. Finally, a dichotomous variable was created to identify women who were either underweight, normal weight or overweight at early pregnancy who **moved into a higher risk BMI category** (overweight or obese) between early pregnancy and 2YPP.

Statistical analysis

The relationship between the exposures of interest (early pregnancy BMI category, GWG category and 1YWR) and covariates were analyzed using oneway ANOVA or Kruskal-Wallis for continuous outcomes, and χ^2 or Fisher's exact tests for categorical outcomes. Post-hoc pair-wise comparisons were examined using the Bonferroni adjustment for multiple comparisons. A correlation matrix (Pearson, *r*) was generated for all the body weight measurements (early pregnancy, before delivery, 1YPP, and 2YPP), using the Sidak multiple comparison adjustment. Unadjusted and adjusted linear and logistic regression models were used to examine the relationships between the primary exposures and outcomes of interest. All models adjusted for time lapse between measurements due to variation in the timing of the measurements. Adjusted models additionally controlled for breastfeeding, smoking, and socioeconomic variables. There was substantial collinearity between the socioeconomic variables. The inclusion of covariates in the adjusted models were determined from a priori theory as well as a battery of statistical methods, including the Akaike Information Criterion, likelihood ratio test, and analysis of deviance using F-test to compare nested models.

Results

Sociodemographic and behavioral variables: Mean ($\pm$ standard deviation) age at delivery was 29.3 $\pm$ 5.3 y. The sample had a mean $\pm$ SD of 14 $\pm$ 2.3 y of education, and was predominantly married or living with partner (91.8%). Over 40% of the women had an income at or below 185% of the PIR. Nearly a quarter of the sample (24%) reported breastfeeding at 1YPP.

GWG and 1YWR

More women gained in excess of the IOM guidelines for GWG (40%) than were within (39%) or below (22%) the guidelines, with a mean $\pm$ SD GWG of 13.5 $\pm$ 5.5 kg. 1YWR was 1.3 $\pm$ 5.8 kg, with nearly a quarter (24%) of the sample having at least 4.55 kg of weight retention at 1YPP. Fifteen percent (n = 61) of the sample had major weight retention at both 1YPP and 2YPP.

LPWC

Mean $\pm$ SD LPWC was 0.01 $\pm$ 4.6 kg. Over half of the women (51%) gained weight between 1YPP and 2YPP. Less than half of the women (42.1%) reached EPW or below at both 1YPP and 2YPP, with 52 (29.9%) of the women who had returned to EPW by 1YPP exceeding EPW by 2YPP. Over half of the women (54.7%) reached their EPW at some point by 2YPP. Thirty-five (11.2%) of the 313 women with early pregnancy BMI < 30.0 kg/m^2 moved to a higher risk BMI category at 2YPP.

The relationship between exposures of interest and potentially confounding variables is shown in **Tables 2.3-2.5**. Early pregnancy BMI category was significantly associated with education (Table 2.3). Obese women had slightly

Table 2. 2. Sample characteristics, N (%)

	N (%)
Age at delivery (y)	
< 25	91 (22.0)
25 to < 35	265 (64.2)
≥ 35	57 (13.8)
Education (y)	
< 15 (not college grad)	255 (61.7)
≥ 15 (college grad)	158 (38.3)
Marriage status	
Married or living with partner	379 (91.8)
Not married or living with partner	34 (8.2)
Poverty (N = 409)	
≤ 185% PIR	167 (40.8)
> 185% PIR	242 (59.2)
Parity	
Nulliparous	156 (37.8)
Parous	257 (62.2)
Smoked during pregnancy or follow-up period	
Yes	109 (26.4)
No	304 (73.6)
Breastfeeding at 1 year postpartum (1YPP) (N = 401)	
Yes	110 (27.4)
No	291 (77.4)
Early pregnancy BMI (kg/m^2)	
< 25.0	214 (51.8)
≥ 25.0, < 30.0	102 (24.7)
≥ 30.0	97 (23.5)
Gestational weight gain (GWG)	
< IOM guidelines	91 (22)
Within IOM guidelines	156 (38)
> IOM guidelines	166 (40)
One year weight retention (1YWR) (kg)	
< 4.55	312 (76)
≥ 4.55	101 (24)
Late postpartum weight retention (LPWR) (kg)[1]	
< 4.55	352 (85)
≥ 4.55	61 (15)
Late postpartum weight change (LPWC, between 1YPP and 2YPP) (kg)	
≤ 0	201 (49)
> 0	212 (51)
Early pregnancy weight (EPW) or below at 1 year postpartum (1YPP)	
YES	174 (42.1)
NO	239 (57.9)
Early pregnancy weight (EPW) or below at 2 years postpartum (2YPP)	
YES	174 (42.1)
NO	239 (57.9)
Early pregnancy weight (EPW) or below at 1YPP or 2YPP	
YES	225 (54.7)
NO	187 (45.3)
Higher risk BMI category at 2YPP (N = 313)[1]	
YES	35 (11.2)
NO	278 (88.8)

[1]Sample restricted to women with early pregnancy BMI < 30.0 kg/m^2.

fewer years of education (approximately -0.89 y, p = 0.01) than normal weight women. GWG was significantly related to parity, with a larger proportion of women exceeding the IOM guidelines being nulliparous, as compared with women who were within or below the guidelines (p = 0.03) (Table 2.4). 1YWR was significantly related to age at delivery, education, income and parity (Table 2.5). Women with < 4.55 kg of weight retention at 1YPP were older (2.4 y, p = 0.0001) and had more education (0.6 y, p = 0.04) than women with ≥ 4.55 kg of weight retention. A greater proportion of women with major 1YWR had incomes below < 185% PIR as compared with women without major 1YWR (54% versus 36.6%, p = 0.002).

Table 2.3. Summary statistics by early pregnancy BMI category[1].

	Early pregnancy BMI (kg/m^2)			
	< 25.0 N = 214	25.0 to < 30.0 N = 102	≥ 30.0 N = 97	*P*[2]
Age at delivery (y)	29.7 ± 5.7	29.4 ± 4.9	28.3 ± 4.8	0.10
Education (y)	14.3 ± 2.4	14.2 ± 2.3	13.4 ± 1.7	0.02
Marriage status				
Married or living with partner	197 (92.1)	95 (93.1)	87 (90.6)	0.67
Not married or living with partner	17 (7.9)	7 (6.9)	9 (9.4)	
Poverty				
≤ 185% PIR[3]	80 (37.7)	38 (38.0)	49 (50.5)	0.09
> 185% PIR	132 (62.3)	62 (62.0)	48 (49.5)	
Parity				
Nulliparous	80 (37.4)	37 (36.3)	39 (40.2)	0.84
Parous	134 (62.6)	65 (63.7)	58 (59.8)	
Smoked during pregnancy or follow-up				
Yes	53 (24.8)	22 (35.5)	26 (24.5)	0.56
No	161 (75.2)	40 (64.5)	80 (75.5)	
Breastfeeding at 1YPP				
Yes	64 (30.9)	26 (26.0)	20 (21.3)	0.21
No	143 (69.1)	74 (74.0)	74 (78.7)	

[1]Mean ± SD or N (%).

[2]Oneway anova or Kruskal-Wallis test for continuous outcomes, or Chi-square/Fisher's exact test of association for categorical outcomes.

[3]PIR = poverty income ratio.

Table 2.4. Summary statistics by gestational weight gain (GWG) category[1].

	GWG category			
	< IOM N = 73	Within IOM N = 147	> IOM N = 193	P^2
Age at delivery (y)	28.9 $\pm$ 5.0[2]	29.7 $\pm$ 5.0	29.1 $\pm$ 5.3	0.16
Education (y)	13.9 $\pm$ 2.2	14.2 $\pm$ 2.4	14.0 $\pm$ 2.2	0.74
Marrital status				
Married or living with partner	69 (94.5)	137 (93.8)	173 (89.6)	0.29
Not married or living with partner	4 (5.5)	9 (6.2)	20 (10.4)	
Poverty				
$\leq$ 185% PIR	43 (58.9)	93 (64.1)	106 (55.5)	0.28
> 185% PIR	30 (41.1)	52 (35.9)	85 (44.5)	
Parity				
Nulliparous	23 (31.5)	47 (32.0)	86 (44.6)	0.03
Parous	50 (68.5)	100 (68.0)	107 (55.4)	
Smoked during pregnancy or follow-up				
Yes	19 (26.0)	43 (29.3)	47 (24.4)	0.60
No	54 (74.0)	104 (70.8)	146 (75.6)	
Breastfeeding at 1 year postpartum				
Yes	17 (23.9)	43 (29.7)	50 (27.0)	0.67
No	54 (76.1)	102 (70.3)	135 (73.0)	

[1]Mean $\pm$ SD or N (%)

[2]Oneway anova or Kruskal-Wallis for continuous outcomes, Chi-square or Fisher's exact test of association for categorical outcomes.

[3]PIR = poverty income ratio.

All within-subject body weight measurements were highly correlated (Bonferroni-adjusted $P < 0.0001$), with $r > 0.90$ between all measurements (**Table 2.6**). The strongest correlation was between body weight at 1YPP and 2YPP ($r = 0.97$). The correlations between early pregnancy body weight with the last pregnancy body weight, weight at 1YPP and weight at 2YPP all exceeded $r = 0.94$.

Table 2.5. Summary statistics by one year weight retention (1YWR) category[1].

	1YWR		
	< 4.55 kg N = 312	$\geq$ 4.55 kg N = 101	P^2
Age at delivery (y)	29.9 $\pm$ 5.1	27.5 $\pm$ 5.5	0.0001
Education (y)	14.2 $\pm$ 2.4	13.6 $\pm$ 1.9	0.04
Marriage status			
Married or living with partner	291 (93.3)	88 (87.1)	0.05
Not married or living with partner	21 (6.7)	13 (12.9)	
Poverty			
$\leq$ 185% PIR	113 (36.6)	54 (54.0)	0.002
> 185% PIR	196 (63.4)	46 (46.0)	
Parity			
Nulliparous	107 (36.6)	49 (48.5)	0.01
Parous	205 (63.4)	52 (51.5)	
Smoked during pregnancy or follow-up			
Yes	85 (27.2)	24 (23.8)	0.49
No	227 (72.8)	77 (76.2)	
Breastfeeding at 1YPP			
Yes	84 (27.6)	26 (26.8)	0.87
No	220 (72.4)	71 (73.2)	

[1]Mean $\pm$ SD or N (%).

[2]Oneway anova or Kruskal-Wallis test for continuous outcomes, or Chi-square or Fisher's exact test of association for categorical outcomes.

[3]PIR = poverty income ratio.

Table 2.6. Correlation matrix (*r*) of body weight measurements at all time points[1,2]

	EPW	LPW	1YPP	2YPP
EPW	-			
LPW	0.95	-		
1YPP	0.95	0.94	-	
2YPP	0.94	0.92	0.97	-

[1]Early pregnancy weight, last pregnancy weight, weight at 1YPP, and weight at 2YPP.

[2]All correlations are significant at p < 0.0001 after adjustment for multiple comparisons.

LPWC

LPWC was unrelated to early pregnancy BMI category or GWG in relation to the IOM guidelines (**Table 2.7**). However, LPWC was inversely related to 1YWR in both adjusted and unadjusted models. On average, women lost

Table 2.7. Coefficient estimates from linear regression analysis predicting late postpartum weight change (LPWC, kg) according to early pregnancy BMI, gestational weight gain (GWG) and one year weight retention (1YWR)[1,2].

	Model 1 N = 413	Model 2 N = 397 Adj. R^2 = -0.01	Model 3 N = 397 Adj. R^2 = 0.05
BMI (kg/m^2)			
< 25.0	REF	REF	REF
$\geq$ 25.0, < 30.0	0.45 $\pm$ 0.6	0.58 $\pm$ 0.6	0.46 $\pm$ 0.6
$\geq$ 30.0	0.59 $\pm$ 0.6	0.54 $\pm$ 0.6	0.83 $\pm$ 0.6
GWG			
< IOM	0.10 $\pm$ 0.7	0.02 $\pm$ 0.7	-0.11 $\pm$ 0.6
Within IOM	REF	REF	REF
> IOM	-0.01 $\pm$ 0.5	-0.28 $\pm$ 0.5	0.33 $\pm$ 0.5
1YWR (kg)			
< 4.55	REF	--	REF
$\geq$ 4.55	-2.0 $\pm$ 0.5***		-2.5 $\pm$ 0.6***

[1]Model 1 adjusted for time between measurements of 1YPP and 2YPP body weight. Model 2 includes early pregnancy BMI and GWG, adjusted for time between measurements, smoking status, breastfeeding at 1YPP, years of education, parity and income. Model 3 includes all variables in Model 2, additionally adjusted for 1YWR.

[2] * P < 0.05, ** P < 0.01, *** P < 0.001

0.11 kg between 1YPP and 2YPP for every additional kilogram of 1YWR (p < 0.001) (see **Appendix A**). The magnitude and significance of this relationship was robust to several alternate model specifications. Women with major 1YWR had significantly greater weight loss between 1YPP and 2YPP than women who were at or below EPW at 1YPP (mean ± S.E. = -1.0 ± 0.3 kg vs. 1.5 ± 0.3 kg, $p < 0.0001$).Risk of LPWG was inversely related to 1YWR, but was unrelated to early pregnancy BMI or GWG in either the adjusted or unadjusted models (**Table 2.8**). In the fully adjusted model, risk of weight gain was 58% lower (95% CI 29% - 75%) for women with major 1YWR.

Table 2.8. Relative risk (95% CI) of late postpartum weight gain[1] according to early pregnancy BMI, gestational weight gain (GWG) and 1-year weight retention (1YWR).[2]

	Model 1 N = 413	Model 2 N = 397 Pseudo R^2 = 0.01	Model 3 N = 397 Pseudo R^2 = 0.05
BMI			
< 25.0	REF	REF	REF
≥ 25.0, < 30.0	1.32 (0.82, 2.13)	1.48 (0.89, 2.47)	1.33 (0.79, 2.26)
≥ 30.0	1.30 (0.80, 2.10)	1.41 (0.84, 2.35)	1.44 (0.85, 2.45)
GWG			
< IOM	1.07 (0.61, 1.87)	1.00 (0.56, 1.78)	0.91 (0.51, 1.65)
Within IOM	REF	REF	REF
> IOM	0.95 (0.62, 1.46)	0.80 (0.50, 1.28)	1.06 (0.65, 1.74)
1YWR (kg)			
< 4.55	REF	--	REF
≥ 4.55	0.48 (0.30, 0.76)**		0.42 (0.25, 0.71)**

[1]Weight at two years postpartum (2YPP) > weight at one year postpartum (2YPP).

[2]Model 1 adjusted for time between measurements of 1YPP and 2YPP body weight. Model 2 includes BMI, GWG, time between measurements, smoking status, breastfeeding at 1YPP, years of education, parity and income.

* $P < 0.05$, ** $P < 0.01$, ***, $P < 0.001$.

LPWR

Among women who gained at least 4.55 kg associated with pregnancy (N = 393), the risk of LPWR (weight at both 1YPP and 2YPP $\geq$ 4.55 kg above EPW) was significantly and positively related to both early pregnancy BMI and GWG in excess of the IOM guidelines in unadjusted and adjusted models (**Table 2.9**). Obese women were 2.53 times (95% CI: 1.32, 4.83, p = 0.01) as likely as normal weight women to have major LPWR in the adjusted model. Overweight women had no increased risk of major LPWR compared with normal weight women. Women who exceeded the IOM guidelines for GWG were 3.44 times as likely (95% CI: 1.59, 7.44, p = 0.002) as those with GWG within the IOM guidelines to have major LPWR. There was no significant

Table 2.9. Relative risk (95%CI) of retaining $\geq$ 4.55 kg of GWG at 1YPP and 2YPP according to early pregnancy BMI and gestational weight gain (GWG)[1,2].

	Model 1 N = 413	Model 2 N = 409 Pseudo R^2 = 0.16
BMI		
< 25.0	REF	REF
$\geq$ 25.0, < 30.0	1.44 (0.70, 2.97)	0.93 (0.42, 2.07)
$\geq$ 30.0	3.44 (1.82, 6.53)***	2.42 (1.21, 4.83)*
GWG		
< IOM	0.80 (0.24, 2.65)	0.65 (0.19, 2.19)
Within IOM	REF	REF
> IOM	4.34 (2.11, 8.94)***	3.44 (1.59, 7.44)**

[1]Weight at 1YPP and weight at 2YPP are both $\geq$ 4.55 kg above EPW.

[2]Model 1 adjusted for time between measurements of early pregnancy and 2YPP body weight. Model 2 includes early pregnancy BMI and GWG, adjusted for time between measurements, smoking status, breastfeeding at 1YPP, years of education, parity and income.

* P < 0.05, ** P < 0.01, ***, P < 0.001

interaction between early pregnancy BMI and GWG in the models predicting major LPWR (results not shown).

Returning to EPW by 2YPP

The likelihood of returning to EPW by 2YPP was unrelated to early pregnancy BMI category in adjusted and unadjusted models (**Table 2.10**). GWG was inversely related to the likelihood of returning to EPW in the unadjusted model

Table 2.10. Relative risk (95% CI) for returning to early pregnancy weight (EPW) by two years postpartum (2YPP) according to early pregnancy BMI, gestational weight gain (GWG) and one year weight retention (1YWR).[1]

	Model 1 N = 413	Model 2 N = 397 Pseudo R^2 = 0.06	Model 3 N = 397 Pseudo R^2 = 0.21
BMI			
< 25.0	REF	REF	REF
$\geq$ 25.0, < 30.0	1.10 (0.68, 1.78)	1.48 (0.87, 2.53)	1.39 (0.50, 1.51)
$\geq$ 30.0	0.72 (0.44, 1.17)	0.88 (0.52, 1.49)	1.19 (0.64, 2.20)
GWG			
< IOM	1.29 (0.71, 2.33)	1.49 (0.80, 2.76)	1.39 (0.71, 2.69)
Within IOM	REF	REF	REF
> IOM	0.53 (0.34, 0.82)**	0.52 (0.32, 0.85)**	0.87 (0.50, 1.51)
1YWR (kg)			
< 4.55	REF	--	REF
$\geq$ 4.55	0.06 (0.03, 0.12)***		0.06 (0.03, 0.13)***

[1]Model 1 adjusted for time between body weight measurements. Model 2 includes GWG and BMI, adjusted for time between measurements, smoking, breastfeeding at 1YPP, years of education, parity and income. Model 3 includes all variables included in Model 2, additionally adjusted for 1YWR.

* P < 0.05, ** P < 0.01, ***, P < 0.001.

and the partially adjusted model, but not in the fully adjusted model. There was a strong inverse relationship between likelihood of returning to EPW and 1YWR in adjusted and unadjusted models ($p < 0.001$). Women with major 1YWR were 94% less likely (95% CI: 87%, 97%) than those with less than 4.55 kg of weight retention at 1YPP to return to EPW by 2YPP.

Moving to a higher risk BMI category

Among women with early pregnancy BMI < 30.0 kg/m^2 (N = 313), the risk of moving to a higher risk BMI category was positively related to GWG above the IOM guidelines and to 1YWR (**Table 2.11**). In the unadjusted model, women who exceeded the IOM guidelines for GWG were 2.85 times (95% CI: 1.22, 6.65) more likely to move to a higher risk BMI category at 2YPP than women

Table 2.11. Relative risk (95% C.I.) of moving to a higher risk BMI category between early pregnancy and 2YPP according to gestational weight gain (GWG) and one year weight retention (1YWR)[1, 2].

	Model 1 N = 313	Model 2 N = 301 Pseudo R^2 = 0.06	Model 3 N = 301 Pseudo R^2 = 0.17
GWG			
< IOM	1.18 (0.34, 4.12)	1.12 (0.32, 4.00)	1.23 (0.33, 4.58)
Within IOM	REF	REF	REF
> IOM	2.85 (1.22, 6.65)*	2.74 (1.14, 6.58)*	1.70 (0.65, 4.43)
1YWR (kg)			
< 4.55	REF	--	REF
≥ 4.55	8.45 (3.98, 17.94)***		7.46 (3.28, 17.01)***

[1]Of women with early pregnancy BMI < 30.0 kg/m^2 (N = 313).

[2]Model 1 adjusted for time between body weight measurements. Model 2 additionally adjusted for smoking status, breastfeeding at 1YPP, years of education, parity and income. Model 3 includes all variables in Model 2, additionally adjusted for 1YWR.

* P < 0.05, ** P < 0.01, ***, P < 0.001.

who gained with the IOM guidelines, although GWG was not related to the risk of moving to a higher risk BMI category in the adjusted model. 1YWR was significantly related to increased likelihood of moving to a higher risk BMI category at 2YPP in adjusted and unadjusted models. Having major 1YWR ($\geq$ 4.55 kg) was associated with a 7.46 (95% CI: 3.28, 17.01) times increased risk of moving to a higher risk postpartum BMI category compared with women with < 4.55 kg of weight retention at 1YPP.

Discussion

This is among the first studies to examine the natural history of maternal body weight between 1YPP and 2YPP, and to distinguish postpartum weight retention from postpartum weight gain. The results indicated a complex relationship between early pregnancy BMI, GWG, 1YWR, and body weight outcomes at 2YPP. Body weight measurements at all 4 time points were highly correlated. Average weight change between 1YPP and 2YPP was close to zero, although more than half of the women gained weight during this period. LPWC was inversely related to 1YWR, but was not significantly related to early pregnancy BMI. GWG was significantly related to LPWC in unadjusted models, but not in models adjusted for 1YWR. In addition, the proportion of the variance explained by the model was substantially more sensitive to the inclusion of 1YWR than of GWG, suggesting that 1YWR explains more of the variation in LPWC than does GWG, supporting the hypothesis that 1YWR fully mediates the effect of GWG on LPWC.

Sixty-one (15%) subjects had **major LPWR** (retained at least 4.55 kg of GWG at 2YPP). This is smaller than the proportion of subjects who had major weight retention at 1YPP in this sample (N = 101, 24%). Approximately one quarter of the women who exceeded the IOM guidelines for GWG had major LPWR. Major LPWR was significantly and positively related to both GWG and early pregnancy BMI in models adjusted for time between measurements, smoking during pregnancy, breastfeeding at 1YPP, education, parity and income. These models cannot be adjusted for 1YWR since it is part of the definition of the outcome variable, which allowed for the distinction between weight retention and postpartum weight gain. The data did not suggest any effect modification between GWG and BMI.

Other studies that have measured maternal body weight beyond 1 year postpartum have revealed similar amounts of weight retention. Average weight retention has ranged from 1.5 kg – 3.0 kg when measured at some point between 12 – 18 months postpartum (22-25), or 0.5 kg – 6.2 kg when measured some time between 2.5 – 15 years postpartum (4, 14, 16, 26, 27)[3]. Two review studies of the relationship between GWG and postpartum weight retention concluded that after accounting for the effects of ageing and self-report bias, the average weight gain due to pregnancy is 0 (20, 21). However, the proportion of women sustaining major retention of GWG ranges from 15 – 20 percent (20). Interestingly, in the present study, approximately the same proportion of women were at least 4.55kg above EPW at 1YPP (N = 101, 25%) as at 2YPP (N = 98, 24%) (see **Appendix A**). However, 38% (N = 37) of the women who were at least 4.55 kg greater than EPW at 2YPP were less than 4.55 kg above EPW at 1YPP, due to weight gain between 1YPP and

[3] **:** Findings from studies with very long follow-ups must be evaluated with respect to the high drop-out rates (for example, up to 75% in a 15-year follow-up study (14))

2YPP. These data demonstrate how failure to account for postpartum weight gain leads to misclassification of postpartum weight retention.

Likelihood of returning to EPW or below by 2YPP was not related to early pregnancy BMI, but was inversely related to GWG in the unadjusted model, and inversely related to 1YWR in both unadjusted and adjusted models, suggesting that 1YWR mediates the relationship between GWG and likelihood of returning to EPW by 2YPP. Women who did not return to EPW by 1YPP were more likely to continue to lose weight between 1YPP and 2YPP than those at or below EPW at 1YPP, but some with weight retention at 1YPP did not return to EPW by 2YPP, especially if 1YWR exceeded 4.55 kg.

Likelihood of moving to a higher risk BMI category between early pregnancy and 2YPP was significantly related to 1YWR. Early pregnancy BMI was not related to likelihood of moving to a higher risk BMI category in unadjusted or adjusted models. GWG was positively related to becoming overweight or obese in the unadjusted and partially adjusted models, but not in the fully adjusted model. The incidence of moving to a higher risk BMI category between early pregnancy and 2YPP was relatively low in this population, with 35 cases in the sample of 413 women (8.5%) over the 2-year follow-up period.

The risk of becoming overweight or obese as a result of a single pregnancy has been explicitly evaluated in only a few studies. The prevalence of high BMI (as defined by BMI $\geq$ 23.9 kg/m^2) increased from 13% to 21% in a study that followed women in Sweden up to 1YPP (7). Another study reported that

8.0% of women with 1 live birth became obese (BMI $\geq$ 30.0 kg/m^2) within 5 years of follow-up, compared to 4.6% among women with no children (27). Similarly, in a study that followed women from an index pregnancy to a second pregnancy, 6.4% of the sample became overweight (BMI $\geq$ 26.0 kg/m^2) between pregnancies (28). The risk reported in the present study of becoming overweight or obese as a result of single pregnancy was low, and within the range of results reported in the literature; 35 women (8.5% of the full sample, 11.2% of the women whose early pregnancy BMI was < 30.0) became overweight or obese between early pregnancy and 2YPP, with 14 women (3.4% of the full sample, 4.4% of women whose early pregnancy BMI was < 30.0) becoming obese (BMI $\geq$ 30.0 kg/m^2) between early pregnancy and 2YPP.

This study confirmed previous findings that early pregnancy BMI, GWG and 1YWR were significantly related to measures of socioeconomic status, including age, education, income and parity. Importantly, the relationship between 1YWR and late postpartum body weight outcomes was significant and robust after controlling for these variables. The relationships between EPW, GWG and late postpartum weight outcomes were more sensitive to the inclusion of covariates in the regression models, although the changes in the magnitude of the regression estimates were small.

In this study, early pregnancy BMI was unrelated to LPWC, LPWG or returning to EPW by 2YPP, but was significantly related to major retention of GWG at 1YPP and 2YPP. There was no evidence of effect modification by GWG. Other studies of varying durations of follow-up have reported mixed results regarding the relationship between pre-pregnancy body size and postpartum weight outcomes (4, 9, 11, 12, 19, 22, 25, 29-31). The results of the present study indicate that these mixed findings may have resulted in part from the use of different outcome definitions in the various studies. One study with similar follow-up time to the current study found a significantly increased risk of weight gain between 6 weeks postpartum and 2YPP associated with early pregnancy obesity (19). That study did not have a measure of maternal body weight between 6 weeks and 2YPP, and did not explicitly control for earlier weight retention in the analysis. In the current study, early pregnancy BMI was not associated with weight change between 1YPP and 2YPP in unadjusted or adjusted analysis. This suggests that the relationship between pre-pregnancy body size and postpartum weight gain may be restricted to the period between 6 weeks and 1YPP. Body weight measurements at several time points between delivery and 2YPP are necessary in order to test this hypothesis.

GWG was unrelated to late postpartum body weight outcomes where adjustment for 1YWR was possible, suggesting that 1YWR fully mediates the effect of GWG on late postpartum body weight outcomes. To our knowledge, only one other study examined early postpartum weight retention in relation to longer term weight retention (4), which indicated that weight retention at 6 months postpartum was a significant positive predictor of weight retention evaluated with respect to pre-pregnancy weight 8 – 10 years later. However, that study did not examine 6 month weight retention in relation to the weight change that occurred between 6 months postpartum and long term follow-up.

Strengths

This study has several strengths. The prospective data collection precludes recall bias that may be present in retrospective studies. In addition, the use of measured body weight at all time points helps to reduce measurement error of the primary exposure and outcome variables. This study specifically examined trends in maternal body weight between 1YPP and 2YPP, and was able to distinguish postpartum weight retention from postpartum weight gain. Recent reviews of the evidence regarding the relationship between GWG and postpartum weight retention indicated a need for further research regarding postpartum maternal weight trends up through the initial 2YPP, noting a scarcity of data of the period after 18 months postpartum and a need for clarification regarding the extent of applicability of the term “postpartum weight retention” (20, 21). Another strength of the use of postpartum weight change as an outcome variable results from the reduced structural bias that is characteristic of studies that relate GWG to weight retention, since both of these variables are calculated with respect to the same baseline body weight (20, 21). The present analysis also addressed the possibility of confounding by adjusting for several behavioral and socioeconomic variables that may be related to the exposures and outcomes of interest.

Limitations

This study had several limitations. First, while the initial response rate of this study was high (over 75%), the women who participated were significantly older, had more years of education and were more likely to be married than eligible women who refused to participate (32). In addition, there were differences between the 413 women who were included in the 2-year postpartum follow-up analysis and the 209 initially-enrolled women who were excluded from this analysis. Variables that differed between the included and excluded women were used as covariates in the analyses. However, these results may not be representative of the original study sample, or the target population. The results presented here indicate that adjusting for the socioeconomic variables that differed between included and excluded women did not substantially alter the magnitude of the relationships between the exposures and outcomes of interest. In particular, the effect of 1YWR on postpartum weight outcomes was notably robust to alternative model specifications.

In addition, this analysis excluded women who were more than 14 weeks pregnant at either 1YPP or 2YPP weight measurements, and who had a baby before the 1YPP measurement or within 6 months of the 2YPP measurement in an effort to obtain maternal body weight measurements that were not affected by a current or recent pregnancy. This methodology helps to make conclusions regarding the influence of GWG on maternal body weight in some women, but excludes from the analysis those women who have multiple babies in quick succession, a group about whom it would be desirable to make conclusions regarding the effect of GWG on long-term maternal body weight. Follow-up to 2 years after the last pregnancy is necessary in this group of women in order to determine whether these results are generalizable to this population.

Finally, due to the sample characteristics, these results are not generalizable to other racial/ethnic population, and may also not be generalizable to populations in other geographic regions, or to those outside the age range of those included in this study.

Methodological issues: Assessment of GWG is often problematic in studies of the relationship between GWG and postpartum body weight. GWG is ideally calculated as the difference between body weight immediately before delivery and pre-pregnancy body weight. Although all body weight variables were calculated from measured body weight, measured pre-pregnancy body weight was not available. Measured or imputed EPW was used to reduce bias due to self-reported pre-pregnancy body weight common to studies of GWG, which is especially problematic because it varies with body weight (20). Measured EPW is expected to be a good approximation of pre-pregnancy body weight since most pregnancy-related body weight occurs in the last two trimesters (1, 20, 22). In addition, a meta-analysis of studies examining the relationship between GWG and postpartum weight retention found that findings of studies based on measured EPW fell within the range of those based on self-reported pre-pregnancy body weight (21). However, the possibility remains in the present study that the use EPW may have underestimated GWG. The degree of underestimation is expected to be invariant with respect to GWG, which may result in a bias towards the null hypothesis regarding the relationship between GWG and postpartum weight outcomes.

Although this study was able to distinguish retention of GWG from weight gain that occurred between 1YPP and 2YPP, a measure of body weight was not available for analysis between delivery and 1YPP for a majority of the sample, or between 1YPP and 2YPP. An increase in mean body weight between 12 and 18 months postpartum has been reported in the literature (24). However, the present study cannot distinguish 1YWR from weight gain that occurred in the first year after delivery, nor can it distinguish body weight trends that may differ between various time points between the available measurements. Several measurements of body weight are required in order to further examine the course of postpartum weight retention. Further, although the use of LPWC as an outcome variable reduces the presence of structural bias between the predictor and outcome variables, this is not the case for the outcomes of returning to EPW or LPWR, since these variables are calculated from the same baseline measurement as GWG. The nature of the research question may never allow for the structural bias in the relationship between GWG and all postpartum weight outcomes to be eliminated. Increased BMI and obesity risk result only from the long-term retention of weight gain (whether it is related to pregnancy or not). Thus, excess GWG and postpartum weight retention will predictably lead to increased maternal BMI. A more informative research question may be whether GWG leads to increased BMI in comparison to weight gain unrelated to pregnancy. Since cumulative weight gain of 1 kg/year is common throughout adulthood (33), and previous research has suggested that weight gain due to pregnancy after accounting for the effects of ageing is essentially 0 (22), pregnancy-related weight gain may in fact be less insidious for long-term obesity risk than non-pregnancy weight gain.

Contribution to the literature and implications for further research

These findings suggest that maternal weight gain is common after 1YPP, indicating that misclassification of postpartum weight retention may be problematic in studies where this gain is unaccounted for. In addition, although high pre/early pregnancy BMI, GWG above the IOM guidelines, and 1YWR may be reasonably thought to suggest a high susceptibility to weight gain in general, these factors were not related to risk of late postpartum weight gain in these women. In fact, women with high 1YWR were far less likely to gain weight between 1YPP and 2YPP as compared with women who were at or below EPW at 1YPP.

The results from this study support the appropriateness of the IOM guidelines for GWG for reducing a mother's risk of retaining excess body weight and returning to EPW by 2YPP. Women with major weight retention at 1YPP ($\geq$ 4.55 kg) were likely to lose weight between 1YPP and 2YPP, but were extremely unlikely to reach their EPW by 2YPP. Longer follow-up is necessary to determine the long-term progression of maternal body weight for these women, and whether or not EPW is achieved at a later time.

The evidence presented in this study indicates that weight change between 1YPP and 2YPP is related to different factors than those affecting GWG and 1YWR. This weight change could reflect the effects of child-rearing that have been suggested by some to account for some of the observed correlation between parity and body weight in women (20, 27). Further research is required in order to better characterize the factors contributing to weight change after 1YPP. The addition of covariates did not substantially increase the proportion of explained variance of the models. Thus, future research is necessary in order to more adequately explain why some women gained weight while others were able to return to EPW or below. In this sample, becoming overweight or obese as a result of a single pregnancy was a relatively rare event, even among women who exceeded the IOM guidelines for GWG, suggesting that major GWG of a single pregnancy was not a strong risk factor for maternal overweight and obesity in this sample.

APPENDICES

Appendix A. Coefficient estimates $\pm$ S.E. or R.R. (95% CI) for linear relationship between one year weight retention (1YWR) and late postpartum weight change (LPWC), late postpartum weight gain (LPWG), returning to early pregnancy weight (EPW) by 2 years postpartum (2YPP), and moving to a higher risk BMI category by 2 years postpartum (OW/OB at 2YPP).

	Model	
	Unadjusted	Fully adjusted
LPWC (kg)	-0.11 $\pm$ 0.02***	-0.13 $\pm$ 0.02***
LPWG	0.97 (0.95, 0.98)***	0.96 (0.94, 0.98)***
EPW at 2YPP	0.77 (0.73, 0.81)***	0.76 (0.72, 0.80)***
OW/OB at 2YPP	1.12 (1.08, 1.17)***	1.14 (1.09, 1.19)***

*** $p < 0.001$

Appendix B. Major weight retention at 1 year postpartum (1YPP) and 2 years postpartum (2YPP).

	2YPP weight $\geq$ 4.55 kg above EPW		
1YPP weight $\geq$ 4.55 kg above EPW	NO	YES	TOTAL
NO	275	37	312 (76%)
YES	40	61	101 (24%)
TOTAL	315 (76%)	98 (24%)	413

Appendix C. Major 2 year weight retention (2YWR, weight at 1YPP and 2YPP ≥ 4.55 kg) by early pregnancy BMI and gestational weight gain (GWG).[1]

	1 year and 2 year weight ≥ 4.55 kg above EPW		
	YES	NO	*P*-value[2]
Total (N = 413)	60 (15.3)	333 (84.7)	--
BMI			
Underweight	1 (1.67)	10 (3.0)	< 0.001
Normal weight	20 (33.3)	183 (55.0)	
Overweight	14 (23.3)	84 (25.2)	
Obese	25 (41.7)	56 (16.8)	
GWG			
< IOM guidelines	3 (5.0)	50 (15.0)	< 0.001
Within IOM guidelines	10 (16.7)	137 (41.1)	
> IOM guidelines	47 (78.3)	146 (43.8)	

[1]Among women with GWG ≥ 4.55 kg

[2]Fisher's exact test of association.

Appendix D. At or below early pregnancy weight (EPW) by 2 years postpartum (2YPP) according to early pregnancy BMI, gestational weight gain (GWG) and one year weight retention (1YWR).

	At or below EPW by 2YPP		
	YES	NO	*P*-value[1]
Total (N = 413)	226 (54.7)	187 (45.3)	--
BMI			
Underweight	7 (3.1)	4 (2.1)	0.5
Normal weight	113 (50.0)	90 (48.1)	
Overweight	59 (26.1)	43 (23.0)	
Obese	47 (20.8)	50 (26.7)	
GWG			
< IOM guidelines	49 (21.7)	24 (12.8)	0.001
Within IOM guidelines	90(39.8)	57 (30.5)	
> IOM guidelines	87 (38.5)	106 (56.7)	
1YWR (kg)			
< 4.55	214 (94.7)	98 (52.4)	< 0.001
≥ 4.55	12 (11.9)	89 (47.6)	

[1]Fisher's exact or chi-square test of association.

Appendix E. Moving to a higher risk BMI category between early pregnancy and 2 years postpartum (2YPP) according to early pregnancy BMI, gestational weight gain (GWG), and one year weight retention (1YWR).

	Higher risk postpartum BMI category by 2YPP		
	YES N (%)	NO N (%)	P[1]
Total (N = 313)	35 (11.2)	278 (88.8)	--
BMI			
Underweight	0 (0.0)	8 (2.9)	0.72
Normal weight	22 (62.9)	181 (65.1)	
Overweight	13 (37.1)	89 (32.0)	
Obese			
GWG			
< IOM guidelines	4 (11.4)	48 (17.3)	0.03
Within IOM guidelines	8 (22.9)	114 (41.0)	
> IOM guidelines	23 (65.7)	116 (41.7)	
1YWR (kg)			
< 4.55	14 (40.0)	236 (84.9)	< 0.001
≥ 4.55	21 (60.0)	42 (15.1)	

[1]Chi-square or Fisher's exact test of association.

Appendix F. Estimates[1] for covariates in models predicting late postpartum weight outcomes[2] adjusted for gestational weight gain, early pregnancy BMI category, and 1-year weight retention category.

	Dependent Variable				
	LPWC (kg)	LPWG	LPWR	EPW2Y	BMICHG
Education (y)	-0.24 ± 0.1*	1.0 (0.9, 1.1)	0.8 (0.7, 0.97)*	1.0 (0.9, 1.1)	1.1 (0.9, 1.3)
Poverty					
≤ 185% PIR	-0.4 ± 0.5	1.0 (0.6, 1.6)	1.2 (0.6, 2.5)	1.1 (0.6, 1.8)	2.1 (0.9, 5.2)
> 185% PIR	REF	REF	REF	REF	REF
Parity					
Nulliparous	REF	REF	REF	REF	REF
Parous	-0.7 ± 0.5	0.9 (0.6, 1.5)	0.6 (0.3, 1.1)	0.9 (0.5, 1.5)	1.6 (0.7, 3.8)
Smoked					
Yes	-1.1 ± 0.5*	0.8 (0.5, 1.2)	0.7 (0.3, 1.5)	1.7 (0.9, 2.9)	0.7 (0.2, 1.8)
No	REF	REF	REF	REF	REF
BF at 1YPP					
Yes	-0.7 ± 0.5	0.8 (0.5, 1.3)	0.9 (0.4, 1.9)	2.0 (1.1, 3.5)*	0.6 (0.2, 1.5)
No	REF	REF	REF	REF	REF

[1]Mean ± SE or R.R. (95% CI).
[2]Late postpartum weight change (LPWC), late postpartum weight gain (LPWG), late postpartum weight retention (LPWR), returning to early pregnancy weight by 2 years postpartum (EPW2Y), and moving to a higher risk BMI category between early pregnancy and 2 years postpartum (BMICHG).
* p < 0.05.

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CHAPTER 3

PRENATAL PSYCHOSOCIAL FACTORS RELATED TO MATERNAL HEALTH BEHAVIORS AND WEIGHT CHANGE BETWEEN 1 AND 2 YEARS POSTPARTUM

Abstract

The influence of psychosocial factors on postpartum health behaviors and weight change is not well understood. The objective of this study was to examine the relationships between two prenatal psychosocial factors (self-efficacy and locus of control) with postpartum eating and exercise behaviors as well as weight change between 1 and 2 years postpartum. Methods involved analysis of data from a prospective observational cohort study of a population-based sample of 413 women seeking prenatal care in upstate New York. Validated measures of self-efficacy and locus of control were obtained via questionnaires from women during pregnancy. Exercise frequency, and frequency of fruit and vegetable intake were measured by questionnaires from women at 2 years postpartum. Path analysis was used to simultaneously examine the direct and indirect relationships between psychosocial, behavioral and weight change variables. Prenatal self-efficacy and locus of control were positively related to postpartum fruit and vegetable intake and exercise frequency. Prenatal self-efficacy was inversely related to 1-year weight retention and positively related to likelihood of returning to early pregnancy body weight by 2 years postpartum. These findings suggest that prenatal psychosocial factors may be predictive of postpartum health behaviors and weight change, and indicate an opportunity to identify women during

pregnancy who may be at higher risk of long-term adverse health outcomes, and who may benefit from behavioral intervention during this period.

Introduction

Pregnancy is a significant life event that may have important implications for the trajectory of maternal health behaviors (1). However, the contribution of specific psychosocial constructs to maternal health behaviors and related outcomes in the postpartum period is not well studied. Self-efficacy (SE) and locus of control (LOC) are constructs originating from health behavior theories that are considered key determinants of health behavior. These constructs share the notion of relating to an individual's perceived certainty or confidence of her ability to execute health behaviors, and have been often investigated in research related to nutrition and exercise behaviors (2), with only limited attention given to pregnant women.

SE, the central concept of Bandura's Social Cognitive Theory, refers to the amount of confidence one has in her ability to perform a specific behavior, in the face of barriers, to achieve a desired outcome (3). SE regarding a specific behavior is hypothesized to predict whether he/she adopts or modifies that behavior (2), and how much time and effort is devoted to that behavior (4).

LOC, a construct originating from Rotter's Social Learning Theory (5), refers to an individual's belief in whether her behaviors and outcomes related to those behaviors are within her own control (internal LOC) or under the control of external forces such as chance or powerful others (external LOC) (6). Individuals with internal LOC ("internals") are predicted to be more likely to perform health behaviors than those with external LOC ("externals"). LOC is a more general, domain-specific characteristic than SE, which is described as a task-specific characteristic (2). In other words, LOC may apply to many behaviors related to health (e.g., eating, smoking), whereas SE is said to apply to a specific behavior, such as food intake or the ability to engage in physical activity. Analysis of these related constructs in concert may contribute to our understanding of their importance to maternal health behaviors and outcomes.

Evidence from studies of non-pregnant adults suggests that SE and LOC are related to adherence to behavioral interventions, adoption of health behaviors, and improved health outcomes from weight-control treatments (7-10). Limited research in pregnant women has demonstrated a positive association between SE and internal LOC with previous success with weight loss as well as with current exercise frequency and fruit and vegetable intake measured concurrently (11) and at 1YPP (11, 12). Another study found no significant relationship between prenatal SE and LOC with pregnancy-associated weight gain (13), suggesting the predominant influences of other biological and environmental variables on this outcome.

It has been hypothesized that prenatal psychosocial factors may predict postpartum health behaviors and weight change (11), and researchers have suggested the importance of designing interventions to modify psychosocial characteristics, such as SE and LOC, in order to influence health behaviors (12, 14, 14, 15). Few studies have examined the temporal relationship between psychosocial factors and health behaviors in pregnant women. The findings of one study showed a positive relationship between SE relating to exercise and fruit and vegetable intake assessed during early pregnancy with changes in those behaviors up to 1 year postpartum (14, 16). A positive relationship between SE and food intake behaviors up to 2 years postpartum among WIC recipients has also been reported (17). Previous findings are limited due to the predominance of cross-sectional evaluation of psychosocial factors and target behaviors. In addition, prior research has not accounted for the potential correlation between related psychosocial variables or allowed for the simultaneous analysis of direct and indirect relationships between psychosocial factors and postpartum health behaviors and weight outcomes.

The investigation of constructs that predict future health behaviors is an important research goal that will facilitate the identification of individuals who are most at risk of poor health behaviors and outcomes, and who will benefit most from behavioral intervention, as well as to aid in the refinement of existing health behavior theories and intervention approaches (18-20). Such information may help to improve the design and delivery of health behavior change interventions during pregnancy, when women may be especially receptive to such changes (21-27).

The objective of this paper is to examine simultaneously the direct and indirect relationships between SE and LOC assessed during the prenatal period and health behaviors at 2YPP, as well as body weight outcomes between 1YPP and 2YPP. Prenatal SE and internal LOC were hypothesized to be related to increased exercise frequency and fruit and vegetable intake at 2YPP, and to increased likelihood of returning to early pregnancy body weight (EPW) by 2YPP. Increased late postpartum exercise frequency and fruit and vegetable intake were hypothesized to be related to weight loss between 1YPP and 2YPP, and to increased likelihood of returning to EPW by 2YPP. Weight retention at 1YPP (1YWR) was hypothesized to be inversely related to prenatal SE and LOC, exercise frequency and fruit and vegetable intake at 2YPP, and to weight change between 1YPP and 2YPP.

Methods

The study sample come from the Bassett Mothers Health Project (BMHP), a prospective cohort study of 622 women who were followed from early pregnancy until 2YPP. Details of the recruitment, enrollment and data collection methods have been described elsewhere (11, 12, 16). Briefly, women seeking prenatal care from the Bassett Healthcare System, which serves a 10-county area of upstate New York, U.S.A., were invited to participate in the study. The sample analyzed in this study includes 413 women (66.4%) from the original cohort who met inclusion criteria for measurements of gestational weight gain (GWG, the difference between last measured pregnancy weight and early pregnancy weight), and body weight at 1YPP and 2YPP. Women were mailed detailed questionnaires once during the prenatal period, and at 1YPP and 2YPP. Height was measured at the first prenatal visit, and body weight at prenatal and postpartum visits by health providers at early pregnancy, within 6 weeks of delivery, and at 1YPP and 2YPP. Study procedures were approved by the Cornell University and Bassett Healthcare Institutional Review Boards.

Variables

Prenatal psychosocial variables: SE and LOC were assessed by the prenatal questionnaire (see **Appendix A** for question wording and response types). The scales, designed to measure weight LOC and SE related to weight control, food intake and exercise, were developed specifically for pregnant women, guided by the theoretical framework of Social Cognitive Theory (3) drawn from existing validated scales used in non-pregnant samples (11). The overall score for each variable was an average of all questions assessing the construct, with higher scores for the SE scale indicating greater SE, and higher scores for the LOC scale indicating a more internal (versus external) LOC. The internal reliability for the SE and LOC scores (r = 0.85 and r = 0.73, respectively) have been established previously (11). Although SE is considered to be task-specific (i.e., relating to a specific behavior), a single SE score for analysis of postpartum outcomes has been recommended due to high inter-factor correlation between items assessing SE regarding weight loss, exercise, and fruit and vegetable intake during early pregnancy (0.31 – 0.42) (11). The present analyses were tested using both the overall SE scale and scales separated for each task. However, results and inferences were not appreciably different between the different models. Therefore, in order to produce a more parsimonious model, these findings present models including only the overall SE factor.

Postpartum behavioral variables: Exercise frequency and fruit and vegetable intake were treated as ordered categorical variables. Exercise frequency was measured on the 2YPP questionnaire by the question, “How often during your free time do you get regular exercise which makes you sweat or breathe hard?", adapted from the Godin Leisure-Time Exercise Questionnaire (28). Possible answers varied from 1 (never) to 4 (often/everyday). Fruit and vegetable intake was measured on the 2YPP questionnaire by the question, "How many fruits and vegetables (fresh, frozen, or canned) do you eat per day?" Possible answers ranged from 1 (less than one a day) to 4 (five a day or more). Data about postpartum behavioral variables were not available for 45 (11%) of the women for fruit and vegetable intake, and 73 (18%) of the women for exercise frequency. No significant differences between psychosocial factors or body weight outcomes were revealed between women with complete and missing data on postpartum health behaviors.

<u>Postpartum body weight variables</u>: The primary body weight outcome was late postpartum weight change (LPWC), a continuous variable calculated as the difference between measured body weight at 1YPP and 2YPP. A dichotomous variable was also created to indicate whether maternal body weight reached EPW or below at some point by 2YPP. Weight retention at 1YPP (1YWR), a continuous variable calculated as the difference between weight at 1YPP and early pregnancy weight (EPW), was included as an intermediate postpartum body weight outcome.

Statistical analysis

Summary statistics were examined using STATA 11 (College Station, TX). Path analysis was used to examine simultaneously the direct and indirect effects of prenatal psychosocial factors on postpartum health behaviors and body weight outcomes using MPlus 5.21 (Muthen & Muthen, 1998-2009). The goal for variable inclusion in these models was to produce a parsimonious model with good explanatory power. Four models were analyzed in order to examine the factors of interest. The first model examined only the effects of prenatal psychosocial factors on postpartum eating and exercise frequency. The subsequent models additionally examined the effects of prenatal psychosocial factors on 1YWR and 2YPP body weight outcomes, the latter of which was specified either as a continuous outcome variable (LPWC) in one model, or a dichotomous variable (likelihood of returning to EPW by 2YPP) in the other. Model fit statistics included χ^2 test of overall model fit (non-significant values indicate good fit) (29), root-mean-square error of approximation (RMSEA), the comparative fit index (CFI) and the Tucker-Lewis Index (TLI). Acceptable model fit is indicated by RMSEA < 0.10, CFI > 0.95, and TLI > 0.90 (30). MPlus handles missing data by estimating the model using all available data, based on variables present for each individual (31). Models that include categorical outcome variables are estimated using the robust weighted least squares estimator with diagonal weight matrix, which gives linear regression coefficient estimates for continuous outcomes and probit regression coefficient estimates for categorical outcomes (31). Categorical outcomes included exercise frequency, fruit and vegetable intake and returning to EPW by 2YPP (Yes/No). Marginal probabilities (the change in probability of the outcome variable associated with a 1-unit change in the independent variable) of the categorical outcomes were calculated for the median values of the independent variables (self efficacy, locus of control = 4, exercise frequency = 3).

Results

Mean ± SD weight change between 1YPP and 2YPP was close to zero, but with a large range (min,max = -24.3, 22.0 kg) (**Table 3.1**). The mean prenatal LOC and SE scores were both close to 4 out of a scale ranging from 1 (external LOC/low SE) to 5 (internal LOC/high SE). Thirty-eight percent of the sample reported consuming at least 3 servings of fruit and vegetables daily, and 27% of the sample reported exercising at least sometime, at 2YPP.

Table 3.1. Sample characteristics (N = 413)

Characteristic	Mean ± SD or N(%)
Prenatal Psychosocial Variables	
Self-efficacy[1] (N = 410)	3.9 ± 0.7
Locus of control[2] (N = 410)	4.0 ± 0.6
Postpartum health behaviors (2 years postpartum, 2YPP)	
No. Fruit and vegetables per day	
< 1	34 (8)
1-2	178 (43)
3-4	129 (31)
5 or more	27 (7)
Unknown/missing	45 (11)
Exercise frequency	
Never	23 (6)
Rarely	87 (21)
Sometimes	170 (41)
Often (Everyday)	60 (15)
Unknown/missing	73 (18)
Maternal body weight outcomes	
Weight change (kg) between 1 and 2 years postpartum	0.01 ± 4.6
Weight at 1YPP or weight at 2YPP ≤ EPW	
YES	226 (54.7)
NO	187 (45.3)

[1]Average score of 8 items, ranging 1 – 5.

[2]Average score of 4 items, ranging 1 – 5.

The path diagrams for the models investigating the effects of prenatal psychosocial factors on postpartum health behaviors and body weight outcomes are given in **Figures 3.1-3.4**. The figures include path coefficient estimates that reached statistical significance, where estimates for continuous outcomes are standardized linear regression coefficients and those for categorical outcomes are probit regression coefficient estimates.

The model examining the effects of prenatal psychosocial factors on postpartum fruit and vegetable intake and exercise frequency demonstrated good fit to the data (χ^2 = 2.3, 1df, p = 0.13, CFI/TLI = 0.98/0.92, RMSEA = 0.055) (Figure 3.1). There were positive direct effects of prenatal SE and LOC

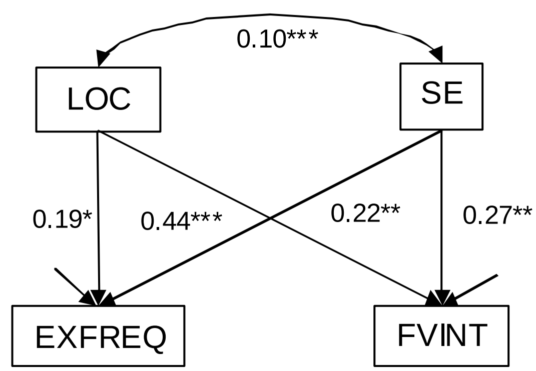

Figure 3.1. Path diagram of the relationships between prenatal self-efficacy (SE) and locus of control (LOC) with exercise frequency (EXFREQ) and fruit and vegetable intake (FV) at 2 years postpartum. Paths are probit regression coefficient estimates. * p < 0.05, ** p < 0.01, *** p < 0.001

on fruit and vegetable intake and exercise frequency at 2YPP. The calculated probabilities from the probit regression coefficient estimates indicated that the probability of exercising “often/everyday” and of $\geq$ 5 servings per day of fruit and vegetable increased for a marginal increase at the median values of prenatal self-efficacy and locus of control (self efficacy and locus of control = 4) (**Table 3.2**).

Table 3.2. Calculated marginal probabilities[1] of health behaviors at 2 years postpartum (2YPP) and returning to early pregnancy weight by 2YPP at middle values of prenatal self-efficacy, locus of control and exercise frequency at 2 years postpartum (2YPP).

	Independent variable		
Outcome variable	Self-efficacy	Locus of control	Exercise frequency
Exercise frequency Often/everyday	0.14	0.05	--
Fruit and vegetable intake ≥ 5 servings per day	0.04	0.03	--
Returning to early pregnancy body weight by 2YPP Yes	--	--	0.06

[1] Marginal probabilities represent the predicted change in probability of reporting "often" exercising or consuming ≥ 5 servings per day of fruit and vegetables associated with a 1-unit increase of the independent variable starting at the median (e.g., self-efficacy, locus of control = 4, exercise frequency = 3).

The expanded model including the effect of 1YWR on LPWC demonstrated good fit to the data (chi-square = 5.2, 5d.f., p = 0.40, CFI = 0.999, TLI = 0.997, RMSEA = 0.009) (Figure 3.2). The effects of prenatal psychosocial factors on postpartum health behaviors were similar in magnitude and significance to the initial model excluding postpartum body weight outcomes. The results from the expanded model indicated an inverse direct effect of 1YWR on LPWC.

The standardized indirect effect of prenatal SE on LPWC was estimated to be 0.05 $\pm$ 0.01 ($p = 0.001$). There were no significant effects of prenatal LOC or postpartum health behaviors on LPWC.

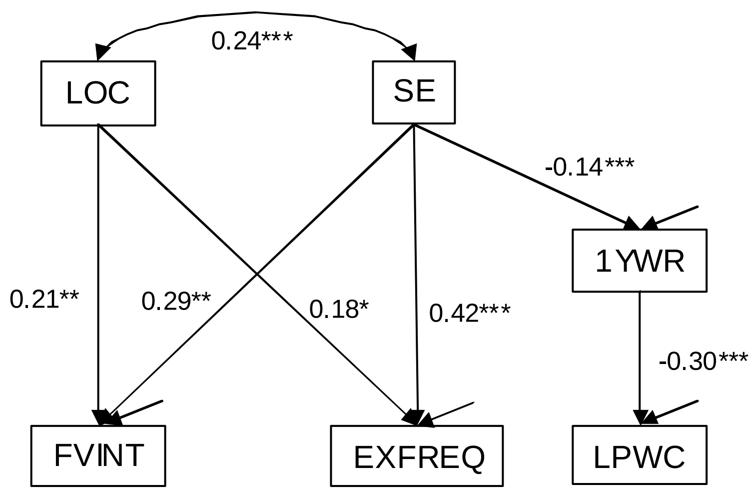

Figure 3.2. Path diagram illustrating relationships between prenatal self-efficacy (SE) and locus of control (LOC) with 1 year weight retention (1YWR), late postpartum weight change between 1 and 2 years postpartum (LPWC), and exercise frequency (EXFREQ) and fruit and vegetable intake (FV) at 2 years postpartum. Paths are probit regression coefficient estimates for categorical outcomes (health behaviors) and standardized linear regression coefficient estimates for SE, LOC and continuous outcomes (1YWR and LPWC). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The fit statistics of the model examining the effects of prenatal psychosocial factors on postpartum health behaviors and likelihood of returning to EPW or below by 2YPP (EPW2Y) indicate very good fit to the data ($\chi^2 = 4.8$, 4df, p =

0.31, CFI/TLI = 0.99/0.98, RMSEA = 0.02) (Figure 3.3). The effects of the prenatal psychosocial factors on postpartum health behaviors were similar in magnitude and statistical significance to the initial model (Figure 3.1). In addition, there was a positive direct effect between postpartum exercise frequency and likelihood of returning to EPW or below by 2YPP. The probability of returning to EPW by 2YPP increased by approximately 6% for each increase in category of exercise frequency (Table 2). The estimate ± SE of the indirect effect of prenatal SE on likelihood of returning to EPW by 2YPP was estimated to be 0.07 ± 0.04, p = 0.053. There were no other significant effects of LOC or fruit and vegetable intake on likelihood of returning to EPW.

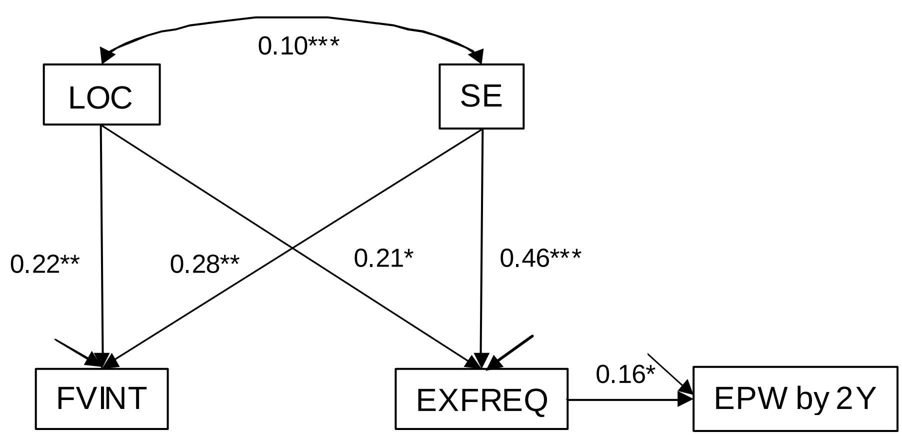

Figure 3.3. Path diagram illustrating relationships between prenatal self-efficacy (SE) and locus of control (LOC) with exercise frequency (EXFREQ) and fruit and vegetable intake (FV) at 2 years postpartum, and likelihood of returning to early pregnancy body weight by 2 years postpartum (EPW2Y). Paths are probit regression coefficient estimates.* p < 0.05, ** p < 0.01, *** p < 0.001

The fit statistics of the model examining the relationships between prenatal psychosocial factors, postpartum health behaviors, 1YWR and likelihood of returning to EPW at 2YPP indicated very good fit to the data (χ^2 = 7.1, 4df, p = 0.13, CFI/TLI = 0.995/0.988, RMSEA = 0.043) (Figure 3.4). The effects of prenatal psychosocial factors on postpartum health behaviors were similar to those in the alternate model specifications. Additionally, there was an inverse

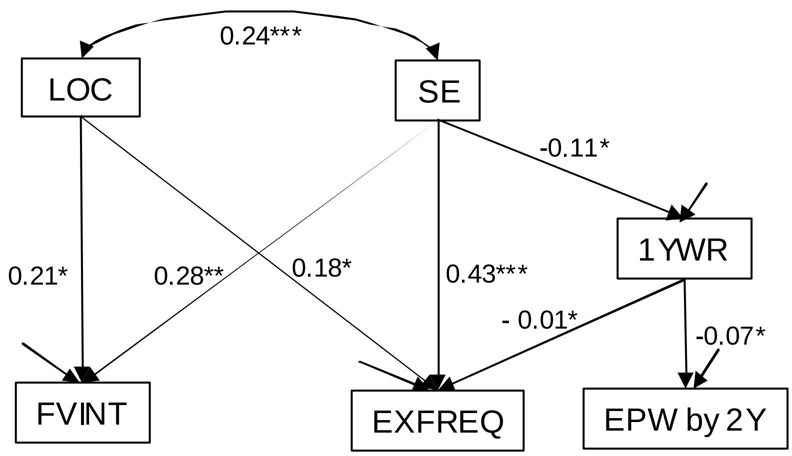

Figure 3.4. Path diagram illustrating relationships between prenatal self-efficacy (SE) and locus of control (LOC) with 1-year weight retention (1YWR), exercise frequency (EXFREQ) and fruit and vegetable intake (FV) at 2 years postpartum, and likelihood of returning to early pregnancy body weight by 2 years postpartum (EPW2Y). Paths are probit regression coefficient estimates. * p < 0.05, ** p < 0.01, *** p < 0.001

direct effect of SE on 1YWR, and of 1YWR on returning to EPW. There was an inverse direct effect of 1YWR on exercise frequency at 2YPP. The effect of exercise frequency on likelihood of returning to EPW by 2YPP, which was significant in the previous model, was not significant in this model, which included 1YWR. The indirect effect of prenatal SE on returning to EPW by 2YPP was estimated to be 0.02 ± 0.08 ($p < 0.001$). In addition, the mean ± SE of the total effect of SE on postpartum exercise frequency (including both direct and indirect effects) was 0.14 ± 0.062 ($p = 0.025$). There were no other significant effects of prenatal LOC and postpartum health behaviors or returning to EPW. The models explain approximately 6.5% of the variance of fruit and vegetable intake, 11.4%-13% of the variance of exercise frequency, 1.3%-2.5% of the variance in 1YWR, 9% of the variance in LPWC, and 2.6-74% of the variance in EPW2Y (**Table 3.3**).

Table 3.3. R^2 estimates for dependent variables in path models[1].

	Model Number			
Dependent Variable	1	2	3	4
FV (2YPP)	0.062	0.065	0.063	0.064
EXFREQ (2YPP)	0.114	0.124	0.114	0.127
1YWR	--	0.025	--	0.011
LPWC	--	0.09	--	--
EPW by 2Y	--	--	0.026	0.741

[1]Fruit and vegetable intake (FV) at 2 years postpartum (2YPP), exercise frequency (EXFREQ) at 2YPP, 1 year weight retention (1YWR), late postpartum weight change (LPWC, weight at 2YPP – weight at 1YPP), and returning to early pregnancy weight (EPW) by 2YPP.

Discussion

This study examined the direct and indirect effects of prenatal psychosocial variables on postpartum health behaviors and body weight outcomes. The robust estimates of the effects of prenatal psychosocial constructs on postpartum health behaviors in the models suggest that prenatal SE and LOC may be predictive of exercise frequency and fruit and vegetable intake at 2YPP. The Social Learning Theories of Bandura and Rotter posit that SE and internal LOC for performing a behavior are related to increased likelihood of engaging in that behavior (5, 32). The direction of the relationships among the variables in the current study was in the hypothesized direction; increased prenatal SE and internal (versus external) LOC were associated with increased exercise frequency ("sometimes" and "often") and fruit and vegetable intake ("3-4" and "$\geq$ 5" servings/day) at 2YPP. The results from these models indicated that 1YWR is related to weight loss between 1YPP and 2YPP, but also to decreased likelihood of reaching EPW by 2YPP.

One unexpected finding was the inverse effect of 1YWR on exercise frequency at 2YPP, which was small, but statistically significant in the model illustrated in Figure 3.4. The inverse effect of SE on 1YWR and the positive effect of SE on postpartum eating and exercise behaviors suggest that women with weight retention at 1YPP are more likely to have low SE and, thus, low execution of health behaviors at 2YPP. Therefore, even though 1YWR was related to weight loss between 1YPP and 2YPP, it was not related to increased exercise frequency or fruit and vegetable intake at 2YPP, suggesting that these behaviors did not mediate the relationship between 1YWR and late postpartum weight change. This may also be indicative of a "relaxed" or "unhurried" attitude towards losing pregnancy-associated weight gain that has been demonstrated in some mothers (1). In addition, a previous study of the influence of weight monitoring (daily weighing) on weight control reported the use of a variety of weight control methods in subjects who observed weight gain (33). Further, an extensive literature suggests that individuals are largely unaware of influences on body weight and related behaviors (34, 35). Thus, mothers with weight retention at 1YPP may lose weight in the following year by unintentional, unperceived and unmeasured methods.

These results extend previous findings regarding the influence of SE and LOC on weight-related health behaviors associated with pregnancy and the postpartum period (11-14) by demonstrating a temporal relationship between SE and LOC measured during pregnancy with behaviors and weight outcomes assessed at 2YPP. Previous research has shown a positive relationship between SE with food intake and exercise frequency assessed during early pregnancy, and between internal LOC (assessed in early pregnancy) and previous success with weight loss (11). A positive relationship has also been reported between health behaviors and SE assessed concurrently at 1YPP (14), and between prenatal exercise SE with change in exercise frequency from pregnancy up to 1YPP (12). In addition, results from an intervention study demonstrated increased fruit and vegetable intake in WIC mothers by improving dietary SE (36). The relationship between prenatal LOC and postpartum eating and physical activity behaviors, and between LOC and SE, which were reported in this study, have not been shown previously, and support the assertion that this construct should be analyzed in concert with other psychosocial variables (2). Together, these findings suggest that women with low weight-related SE and weight LOC during pregnancy may particularly benefit from interventions designed to improve these characteristics and encourage healthy eating and exercise behaviors in the postpartum period, when women may be inclined to discontinue to some extent healthy behaviors that are adopted during pregnancy (37, 38).

This study revealed a positive, indirect effect of prenatal SE on likelihood of returning to EPW by 2YPP via the effect of SE on 1YWR, whereby higher SE was related to reduced 1YWR. To our knowledge, this is the first study to show a relationship between psychosocial factors and postpartum weight change. This may have resulted from the use of analytical methods that allowed for the simultaneous examination of direct and indirect effects of psychosocial factors on postpartum weight outcomes, which has not been utilized in other research of pregnant women.

Despite the assumptions of causality stipulated by path analysis, correlations found between psychosocial constructs and health behaviors should be interpreted with caution, and not assumed to provide evidence either for causality or temporality between the variables (39). This is especially true of associations found in cross-sectional studies. Prospective studies are also not exempt from this issue due to confounding resulting from the influence of past behaviors on psychosocial constructs, and the strong relationship between past behaviors and future behaviors (39). In the present study, several aspects help to reduce the bias that may be inherent to other prospective studies of psychosocial constructs and health behaviors. First, exercise frequency and fruit and vegetable intake as measured prenatally were significantly different ($p < 0.0001$, $p < 0.05$, respectively, results not shown) from those measured at 2YPP, indicating that the strong correlation normally found between past and future behavior is not as applicable in this study. This may be due to the experience with pregnancy that occurred between the assessment of prenatal psychosocial constructs and postpartum behaviors and weight outcomes. Pregnancy is a naturally occurring event that may substantially alter perceptions about resources and capacity to engage in health behaviors (1). Factors influencing health behavior prior to and during pregnancy may differ from those influencing postpartum health behaviors. In addition, the present study demonstrated a relationship between prenatal SE with postpartum body weight outcomes, suggesting that prenatal psychosocial constructs are related not only to health behaviors, but also to the health outcomes associated with those behaviors. Together, these findings reduce the likelihood of confounding normally present in studies of the relationship between psychosocial constructs and health behaviors, and help to support the validity of the findings regarding the temporal relationship between prenatal psychosocial factors and postpartum health behaviors and weight outcomes.

This study has several limitations, including selection bias, missing data for postpartum health behaviors, and lack of racial/ethnic diversity of the sample. Differences of socioeconomic variables between the study population and those who initially refused to participate were small but statistically significant (12). Participants were older, more educated and more likely to be married than those who refused. Those who refused to participate may be more likely to be unhealthy and suffer adverse body weight outcomes as a result of pregnancy. In addition, enrolled women who were not included in this analysis were significantly younger, less educated, and less likely to be parous and to be low income than women with complete data on body weight up to 2YPP.

There was also a significantly higher proportion of lower income than higher income women with missing values for postpartum health behaviors, although no differences were shown according to education, marital status, or parity. Thus, these results may not be representative of the target or source populations. Finally, these results may not be generalizable to other racial/ethnic populations or to those outside the geographic region or age range of the sample.

Despite these limitations, these findings suggest that prenatal psychosocial factors influence postpartum health behaviors and body weight outcomes through direct and indirect pathways in this sample. These results should be replicated in other populations to determine whether, in clinical practice, measures of SE during the prenatal period may help to identify women who may be anticipated to struggle more with returning to EPW in the postpartum period. Since pregnancy is a time in the life course when women are more likely to modify their health behaviors, future research is needed to determine whether interventions during this period to improve SE and to encourage healthy behaviors in the prenatal and postpartum periods may help more women to return to EPW after pregnancy.

APPENDICES

Appendix A. Wording of questions assessing prenatal self-efficacy and locus of control (11).

Item category and wording
Locus of Control questions[1]
1. Whether my weight changes is up to me.
2. If I eat right, and get enough exercise and rest, I can control my weight the way I want.
3. Being the right weight is mainly good luck.[2]
4. No matter what I try to do, if I gain or lose weight, or stay the same, it is just going to happen.[2]
Self-efficacy questions[3]
How sure are you that you can:
1. Fit into your regular clothes
2. Take off any extra weight you gain
3. Get back in shape
4. Eat balanced meals
5. Eat foods that are good for you and avoid foods that are not
6. Eat foods that are good for you even when family or social life takes a lot of your time.
7. Get regular exercise.
8. Get regular exercise even when family or social life takes a lot of time.

[1] Response categories were “strongly agree”, “agree”, “neither agree or disagree”, “disagree”, and “strongly agree”, coded from 1 – 5.
[2] Responses were reversed coded so that high values indicated more internal (versus external) locus of control.
[3] Response categories were “very unsure”, “somewhat unsure”, “neither sure or unsure”, “somewhat sure”, “very sure”, coded from 1 – 5, with higher values indicating increased self-efficacy.

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CHAPTER 4

RELEVANCE OF PROSPECT THEORY TO CONCEPTUALIZATION OF WEIGHT CHANGE

Abstract

Previous researchers have suggested a need for further development of the theoretical framework guiding behavioral interventions to address obesity. The objective of the current study was to examine the relevance of Prospect Theory to understanding individuals' conceptualization of weight change outcomes. According to Prospect Theory, an individual's valuation of a particular outcome is determined with respect to their particular "reference point", suggesting that weight changes of different amounts and directions may be evaluated with respect to an individual's current body weight status. A survey was administered online to women of reproductive age at one university in upstate New York. Women were asked to indicate perceived importance, difficulty, and likelihood of changing behaviors to lose weight or prevent weight gain of specific amounts. Results indicated that perceived importance of weight gain exceeds that of weight loss above 2 – 5 lb, although the opposite is true for a 2 – 5 lb change. Perceived difficulty of weight gain is lower than weight loss of amounts greater than 2 – 5 lb, and is the same as that of 2 – 5 lb. Women report being more likely to change behaviors to prevent weight gain greater than 6 – 10 lb than for weight losses of the same amount, but they are less likely to change behaviors to prevent a 2 – 5 lb weight gain than a 2 – 5 lb weight loss. Likelihood of changing behaviors to produce a 6 – 10 lb weight change was positively related to ratings of

importance, and negatively related to ratings of difficulty. All ratings of importance, difficulty and likelihood were significantly related to current body size (the “body weight reference point”). These findings suggest the relevance of Prospect Theory in individuals’ valuation of weight-related outcomes, and indicate that there may be a need for increased advocacy of the prevention of small amounts of weight gain to prevent weight gain in women of reproductive age.

Introduction

Recent reviews of randomized clinical trials to reduce obesity have revealed mixed results in terms of initial or sustained effects on body weight or body fat content, and indicated a need for a more comprehensive theoretical framework to assist the design of behavioral interventions (1). The goal of the present study was to examine the relevance of concepts from Prospect Theory to understanding women’s conceptualization of weight change.

Prospect Theory (2) is an area of decision theory used in economics that describes an individual’s decisions as being dependent on her reference point, which is generally taken to refer to the status quo (3). The theory, which was developed to address some of the demonstrated violations of the assumptions of Expected Utility Theory, specifies a “value function” with three essential properties. First, value is determined with respect to a reference point. Second, “gains” (prospects that improve the status quo) are valued disproportionately less than “losses” (prospects that worsen the status quo). Third, the value function is marginally decreasing with increasing magnitudes of gains and losses, such that large gains and losses are valued less than small gains and losses. This value function is illustrated in **Figure 4.1**.

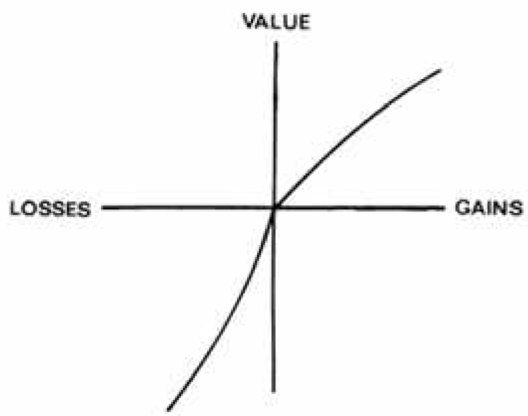


Figure 4.1. Value as a function of prospects that improve (gains) or worsen (losses) the status quo (2).

The potential relevance of the reference point to individuals' conceptualization of weight change has not been fully explored in the literature, which may have implications for the development of behavioral interventions. Many health behavior theories used in clinical research (e.g., Social Cognitive Theory (4), Transtheoretical Model (5), Theory of Reasoned Action/Planned Behavior (6, 7), Health Belief Model(8)) share in common the tenet that for an individual to engage in or change behavior, the outcome of that behavior must have value for the individual that exceeds the perceived costs of that behavior. However, these theories suggest only vaguely the determinants of the outcome value. This study sought to explore how the "reference point" concept of Prospect Theory relates to women's perceived value of weight change outcomes.

The definition of a reference point is not well defined in the literature (2). Therefore, two definitions of the “body weight reference point” (BWRP) were used in this analysis; body mass index (BMI, kg/m^2) was used as an objective representation of the BWRP, and the difference between current and desired body weight (CBW – DBW, lb) was used as a subjective representation of BWRP. For individuals who are at or above their desired body weight, a “gain” (improvement in status quo) is interpreted to refer to a weight loss, while a “loss” (worsening of status quo) refers to a weight gain. Thus, Prospect Theory predicts that an individual’s subjective value of a weight gain of a certain amount is disproportionately larger than that of a weight loss of the same amount. In addition, the theory predicts that an individual’s subjective value of weight change will vary according to the BWRP, such that an individual with high BMI or a large discrepancy between CBW and DBW would evaluate a specific amount of weight change differently than would an individual with a healthy BMI or a low discrepancy between CBW and DBW.

Subjective ratings of importance of preventing weight gains and producing weight losses of several amounts, along with the reported likelihood of changing behaviors to produce specific amounts of weight change and the perceived difficulty of producing specific amounts of weight change were assessed in a sample of adult women. Perceived importance was used as a measure of subjective value of weight change outcomes, while perceived difficulty was used to measure subjective costs associated with weight change outcomes. Reported likelihood of changing behaviors was used as a measure of behavioral intent. Three hypotheses were examined: a) subjective ratings of the importance, difficulty, and likelihood of changing behaviors to prevent a weight gain of a specific amount will differ from those of producing a weight loss of the same amount, b) subjective ratings of importance, difficulty and likelihood of changing behaviors to produce specific amounts of weight change will vary with respect to an individual's BWRP as defined by BMI and the difference between current and desired body weight, and c) reported likelihood of changing behaviors to produce weight change will be positively related to ratings of importance of weight change and inversely related to ratings of difficulty of weight change. The first two hypotheses test the relevance of the reference point construct from Prospect Theory towards understanding women's conceptualization of weight change outcomes, while the third hypothesis examines the predictions of health behavior theories and behavioral economics regarding the influence of the perceived benefits and costs of producing weight change on the likelihood of engaging in behaviors to produce weight change.

Methods

Survey procedures

A pilot-tested, quantitative survey was administered online to females at one university in upstate New York, U.S.A. A random sample of 1655 faculty, staff, and graduate/professional students was invited by email to participate in the survey. One follow-up email was sent in attempt to increase participation. The response rate was 22.4% (N = 371). After exclusions for being outside the age range of 20 and 55 years, BMI < 18.5 kg/m^2, current pregnancy and any current or previously diagnosed eating disorder (N = 73), the final analytical sample included 298 respondents. Procedures were approved by the Cornell University Institutional Review Board (IRB).

Variables

The survey asked subjects to state their age, race, ethnicity, household income, occupation and education level. In addition, the survey asked questions regarding self-reported height and weight and ideal/desired body weight ("How much would you like to weigh?", free response), as well as satisfaction with, and perception of, current body size ("How satisfied are you with your current body weight?", 1 ("not at all …") to 9 ("very …)"; "Would you say your current body size is 1- too thin, 5- about right, 9- too heavy?"). Respondents were also asked to indicate whether they wished to gain weight, lose weight, or stay the same weight (fixed response). Body mass index (BMI = kg/m^2) as calculated from reported height and weight was used as a categorical according to normal weight (BMI < 25.0), overweight (BMI $\geq$ 25.0 < 30.0), and obese (BMI $\geq$ 30.0). The difference between current and desired body weight (CBW – DBW, lb) was used as a dichotomous variable, according to whether CBW – DBW $\geq$ 25 lb or < 25 lb, a cut point determined from exploratory analysis of the unadjusted relationship between CBW – DBW and ratings of importance of a 2 – 5 lb weight gain (data not shown). Variables indicating the quintile distributions of BMI and CBW – DBW were also used in the analysis.

<u>Outcome variables</u>: Respondents were asked a series of questions about the importance, difficulty, and satisfaction associated with specific amounts of weight change, and the likelihood of changing behaviors to produce specific amounts of weight change (see **Appendix A** for question stems and response options). To test the hypothesis that weight gain would be valued more than an equivalent range of weight loss (hypothesis 2), questions were posed once

in reference to preventing weight gain, and once in reference to producing weight loss. All respondents (N = 298) were asked questions regarding preventing weight gain. However, only respondents indicating they desired to lose weight (N = 242, 81%) were asked questions regarding weight loss. Responses for most questions ranged from 1 ("not at all...") to 9 ("very…"). Questions were pilot-tested among 20 non-participants in order to assess understandability, acceptability, sensitivity and face validity, and were modified as necessary.

Statistical analysis

Sample characteristics were described for the predictor and outcome variables, both for the entire sample and by BMI category.

To examine the first hypothesis, the Wilcoxon matched pairs signed ranks test (for the equality of the rank distributions) and the sign test of matched pairs (for the equality of the medians) were used to compare within-subject responses to ratings (importance, difficulty, likelihood) of preventing specific amounts of weight gain with ratings related to producing the same amounts of weight loss.

To test the second hypothesis, multivariate regression analysis was used to examine the relationships between the reference point definitions with each category of response (i.e., importance, difficulty, and likelihood). The outcome measure for each regression model was the set of responses to all specified amounts of weight gain or loss for each response category (i.e., 2-5 lb, 6- 10 lb, 11- 20 lb, 21- 40 lb, 41+ lb). The regression for each of the 6 outcomes for ratings of importance, difficulty and likelihood regarding all amounts of weight gain and loss were replicated for both reference point definitions. Due to the skewness of the BMI and CBW – DBW variables, and to facilitate interpretability, these variables were categorized according to two binary variables indicating whether the subject was overweight (BMI $\geq$ 25.0 kg/m^2) or not, and whether CBW – DBW was $\geq$ 25 lb or < 25 lb, respectively.

To test the third hypothesis, path analysis was used to analyze simultaneously the direct and indirect relationships between the reference point and subjective ratings of importance, difficulty and likelihood of producing weight changes. Separate analyses were examined for weight loss and weight gain outcomes. MPLUS version 5.21 was used to conduct this analysis (MPlus User's Guide)**.** Model fit statistics included χ^2 test of overall model fit (non-significant values indicate good fit) (9) root-mean-square error of approximation (RMSEA), the comparative fit index (CFI) and the Tucker-Lewis Index (TLI). Acceptable model fit is assumed for RMSEA < 0.10, CFI > 0.95, and TLI > 0.90 (10). MPlus estimates the model using all available data (11). Models including categorical variables are estimated using the robust weighted least squares estimator with diagonal weight matrix, whereby paths for categorical outcomes are probit regression coefficients, and those for continuous outcomes are linear regression coefficient estimates (11).

Results

The current body weight of the sample was 146.9 $\pm$ 33.9 lb (66.8 $\pm$ 15.4 kg) (mean $\pm$ SD) (**Table 4.1**). Current BMI was in the upper range of normal weight (24.5 $\pm$ 5.4 kg/m^2). Desired body weight was 130.4 $\pm$ 17.8 lb (59.3 $\pm$

8.1 kg), or a BMI = 21.7 $\pm$ 2.5 kg/m^2. The sample was 31.6 $\pm$ 8.8 years. Most respondents (66%) were students. The sample is highly educated, with over 80% having at least a bachelor's degree. The sample was predominantly white (72.3%) and has never smoked (71.9%). There was a wide range of household incomes.

The sample predominantly reported a desire to lose weight (81.2%), with a difference between current and desired body weight of 16.6 $\pm$ 21.8 lb (7.5 $\pm$ 9.9 kg), or a 2.8 $\pm$ 3.6 kg/m^2 difference in current and desired BMI (**Table 4.2**). On average, the sample reported being "somewhat satisfied" with their current body weight, and perceived themselves as being slightly heavier than "about right" (6.3 $\pm$ 1.3 on a 1-9 point scale). Over 95% of the sample considered an acceptable weight range to fluctuate within 2-5 lb of their current body weight. Slightly more than half of the sample (56.7%) reported currently using strategies to prevent weight gain, while 76.9% reported currently using strategies to reduce their current body weight.

Overweight and obese women, and women reporting a difference between current and desired body weight of at least 25 lb, were less satisfied with their current body weight, perceived their body size as being closer to "too heavy", and were more likely to report a desire to lose weight than normal weight women or women within 25 lb of their desired body weight. In addition, women with BMI $\geq$ 25 kg/m^2 and with CBW – DBW $\geq$ 25 lb were more likely to report currently using strategies both to prevent weight gain and to lose weight

Table 4.1. Subject characteristics (N = 298)

	Mean $\pm$ SD or N (%)
Current body weight (lb)	
98 < 120	40 (13.4)
120 < 140	118 (39.6)
140 < 160	62 (20.8)
160 < 180	28 (9.4)
180 - 320	50 (16.8)
Current BMI (kg/m^2)	
Normal weight (18.5 $\leq$ BMI < 25.0)	205 (68.8)
Overweight (25.0 $\leq$ BMI < 30.0)	46 (15.4)
Obese (BMI $\geq$ 30.0)	47 (15.8)
Age (y)	
22 < 30	160 (53.7)
30 < 40	49 (16.4)
40 $\leq$ 55	50 (16.8)
Unknown/missing	39 (13.1)
Country of origin	
United States	220 (73.8)
Outside U.S.	57 (19.1)
Unknown/missing	21 (7.1)
Job	
Student	203 (68.1)
Faculty	17 (5.7)
Staff	57 (19.1)
Missing/unknown	21 (7.0)
Education	
H/S or GED	13 (4.4)
Associate's degree	8 (2.7)
Bachelor's degree	127 (42.6)
Graduate/Prof degree	129 (43.3)
Missing/unknown	21 (7.0)
Race	
White	224 (75.2)
Other	53 (17.8)
Unknown/missing	21 (7.0)
Ethnicity	
Not Hispanic/Latina	261 (87.6)
Hispanic/Latina	14 (4.7)
Unknown/missing	23 (7.7)
HH Income ($)	
<$20, 000	23 (7.7)
$20, 000-$40, 000	85 (28.5)
$41, 000-$60, 000	53 (17.8)
$61, 000-$80, 000	37 (12.4)
$81, 000-$100, 000	30 (10.1)
>$100, 000	44 (14.8)
Unknown/missing	26 (8.7)
Smoking status	
Never	223 (74.5)
Former	37 (12.4)
Current	15 (5.0)
Unknown/missing	23 (7.7)

Table 4.2. Weight change variables by BMI and the difference between current and desired body weight (CBW – DBW) (N = 298).[1, 2]

		BMI (kg/m^2)		CBW – DBW (kg)	
	N (%)	< 25	$\geq$ 25	< 11.4	$\geq$ 11.4
Desired weight outcome					
Lose weight	242 (81.2)	149 (72.7)	93 (100)***	178 (76.0)	64 (100)***
Stay same	54 (18.1)	54 (26.3)	0 (0)	54 (23.1)	0 (0)
Gain weight	2 (0.7)	2 (1.0)	0 (0)	2 (0.9)	0 (0)
CBW – DBW (kg)					
< 11.4	243 (78.6)	203 (99.0)	31 (33.3)***	N/A	N/A
$\geq$ 11.4	64 (21.5)	2 (1.0)	62 (66.7)		
Satisfaction with current body weight (1 = not at all, 9 = very)	4.9 $\pm$ 2.4	5.9 $\pm$ 2.0	2.7 $\pm$ 1.6***	5.7 $\pm$ 2.0	2.0 $\pm$ 1.3***
Body size perception (1 = too thin, 5 = about right, 9 = too heavy)	6.3 $\pm$ 1.3	5.7 $\pm$ 0.9	7.6 $\pm$ 1.1***	5.8 $\pm$ 0.9	8.1 $\pm$ 0.9***
Acceptable weight range					
< 2 lb	91(30.5)	72 (35.1)	19 (20.4)*	78 (33.3)	13 (20.3)
2 – 5 lb	194 (65.1)	125 (61.0)	69 (74.2)	147 (82.8)	47 (73.4)
6 – 10 lb	11 (3.7)	7 (3.4)	4 (4.3)	8 (3.4)	3 (4.7)
11 – 20 lb	2 (0.7)	1 (0.5)	1 (1.1)	1 (0.4)	1 (1.6)
Currently using strategies to prevent weight gain					
Yes	169 (56.7)	149 (72.7)	80 (86.0)*	173 (73.9)	56 (87.5)*
No	129 (43.3)	56 (27.3)	13 (14.0)	61 (26.1)	8 (12.5)
Currently using strategies to lose weight					
Yes	229 (76.9)	96 (46.8)	73 (78.5)***	114 (48.7)	55 (85.9)***
No	69 (23.1)	109 (53.2)	20 (21.5)	120 (51.3)	9 (14.1)

[1]All values are means $\pm$ SD.

[2]Asterisks (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) denote significant differences according to the Fisher exact test for categorical outcomes or the nonparametric median test for continuous outcomes.

than normal weight women and those within 25 lb of DBW. Overweight women were more likely to report an acceptable weight range of between 2 – 5 lb, and less likely to report an acceptable weight range of less than 2 lb compared with normal weight women ($p < 0.05$).

Hypothesis 1:

Evidence from within-subject comparisons of ratings of importance, difficulty, and likelihood of changing behaviors to prevent weight gains of specified amounts with those of producing weight losses of the same amounts provide support for the first hypothesis, that ratings would vary with respect to the direction of the weight change outcome (**Figure 4.2**). There were several significant differences in subjective ratings. The perceived importance of preventing a 2 – 5 lb weight gain was lower than that of a 2 – 5 weight loss, whereas the importance of preventing all greater amounts of weight gain was higher than that of producing the same amounts of weight loss ($P < 0.0001$). Perceived difficulty of preventing a 2 – 5 lb weight gain was not different from that of producing a 2 – 5 lb weight loss, although the perceived difficulty of preventing greater amounts of weight gain was higher than that of producing the same amounts of weight loss ($P < 0.0001$). The reported likelihood of changing behaviors to prevent 2 – 5 lb of weight gain was lower than that of producing a 2 – 5 lb weight loss ($P < 0.0001$). For all amounts of weight change above 2 – 5 lb, reported likelihood of changing behaviors to prevent weight gain was higher than that of producing weight loss ($P < 0.0001$).

Hypothesis 2:

The two BWRP definition variables (BMI category and CBW – DBW category) were significantly related overall to ratings of importance, difficulty and likelihood of changing behaviors to produce all amounts of weight change (**Table 4.3**), supporting the hypothesis that valuations of weight change outcomes are dependent on the BWRP. The BWRP variables were positively related overall to importance of weight change ($p < 0.0001$) and likelihood of changing behaviors to produce weight change ($p < 0.05$ for preventing weight gain, $p < 0.0001$ for producing weight loss), as well as with perceived difficulty of preventing weight gain ($p < 0.0001$). There was an overall inverse relationship between BWRP variables and perceived difficulty of losing weight ($p < 0.0001$).

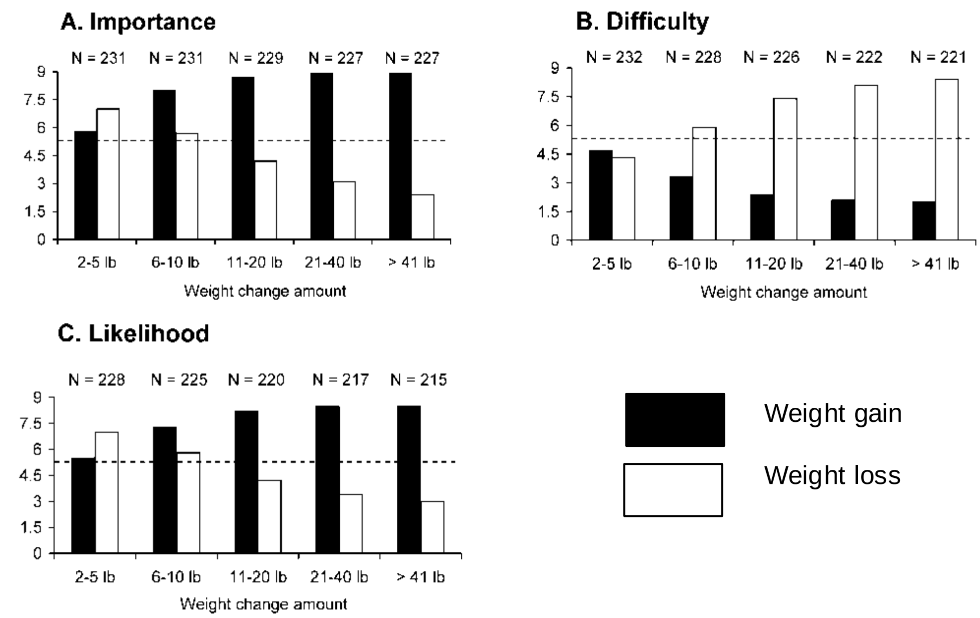


Figure 4.2. Subjective ratings of (A) importance, (B) difficulty, and (C) likelihood of preventing weight gain and producing weight loss.[1-3]

[1]All ratings ranged from 1 ("not at all…") – 5 ("somewhat…") – 9 ("very…").

[2]All comparisons are significantly different ($P < 0.0001$) according to the Wilcoxon matched pairs signed ranks test and the sign test of matched pairs, except the comparison between difficulty of weight change of 2 – 5 lb ($P_{rank} = 0.14$, $P_{median} = 0.56$).

[3]Responses from participants indicating a desire to lose weight (N = 242).

Table 4.3. β**-coefficient estimates + S.E. from unadjusted multivariate regression analyses predicting importance, difficulty and likelihood of preventing all amounts of weight gain and producing all amounts of weight loss according to BMI[1] and the difference between current and desired body weight (CBW – DBW)[2].**

[1]Comparing subjects with BMI $\geq$ 25.0 kg/m^2 to those with BMI < 25.0 kg/m^2.

[2]Comparing subjects with CBW – DBW $\geq$ 25.0 lb with those with CBW – DBW < 25.0 lb.

[3]*P*-value for heading indicates significance of Wald test that the coefficient for the grouping variable is = 0 for all amounts of weight gain; *P*-value for individual weight gain amounts indicates significance of coefficient estimate for specific weight gain amount within the multivariate regression. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	RESPONSE	RANGE OF WEIGHT CHANGE (lb) 2 – 5	6 – 10	11 – 20	21 – 40	> 41	P^3
GAIN	Importance						
	BMI	1.5 ± 0.3***	0.6 ± 0.2**	0.09 ± 0.1	0.1 ± 0.1	0.1 ± 0.09	< 0.0001
	CBW-DBW	1.7 ± 0.3***	0.6 ± 0.2**	0.05 ± 0.1	0.05 ± 0.1	0.1 ± 0.1	< 0.0001
	Difficulty						
	BMI	0.4 ± 0.3	0.8 ± 0.3**	1.1 ± 0.2***	0.9 ± 0.2***	0.9 ± 0.3***	< 0.0001
	CBW-DBW	0.5 ± 0.3	1.1 ± 0.3***	1.5 ± 0.3***	1.3 ± 0.3***	1.4 ± 0.3***	< 0.0001
	Likelihood						
	BMI	0.5 ± 0.3	0.1 ± 0.3	0.06 ± 0.2	0.2 ± 0.2	0.3 ± 0.2	0.04
	CBW-DBW	0.3 ± 0.3	-0.2 ± 0.3	0.05 ± 0.3	0.2 ± 0.2	0.4 ± 0.3	0.02
LOSS	Importance						
	BMI	1.1 ± 0.3***	3.2 ± 0.3***	4.8 ± 0.3***	4.4 ± 0.3***	2.9 ± 0.3***	< 0.0001
	CBW-DBW	1.0 ± 0.3**	3.1 ± 0.4***	5.2 ± 0.4***	5.9 ± 0.3***	4.3 ± 0.3***	< 0.0001
	Difficulty						
	BMI	-0.7 ± 0.3*	-1.4 ±0.3***	-1.3 ±0.3***	-0.6 ±0.2*	-0.1 ± 0.2	< 0.0001
	CBW-DBW	-0.8 ± 0.3**	-1.4 ± 0.3***	-1.5 ± 0.3***	-1.0 ± 0.3***	-0.4 ± 0.3	< 0.0001
	Likelihood						
	BMI	0.5 ± 0.3	2.2 ± 0.4***	3.4 ± 0.4***	3.2 ± 0.4***	2.3 ± 0.4***	< 0.0001
	CBW-DBW	0.8 ± 0.3*	2.4 ± 0.4***	4.2 ± 0.4***	4.4 ±0.4***	3.6 ± 0.4***	< 0.0001

For regressions predicting perceived importance of specific amounts of weight gain, there was a positive relationship between BWRP variables and perceived importance of a 2-5 lb weight gain ($p < 0.001$) and a 6-10 lb weight gain ($p < 0.01$), but the coefficient estimate was not significant for importance of larger amounts of weight gain. There were positive relationships between BWRP variables and perceived importance of each amount of weight loss. Within individual comparisons of perceived difficulty of weight gain, there were positive relationships for all amounts of weight gain except for the 2-5 lb range. BWRP was inversely related to difficulty of producing all amounts of weight loss except for the > 41 lb range. BWRP variables were positively related to likelihood of changing behaviors to produce all amounts of weight loss, with the exception that BMI category was not related to perceived likelihood regarding a 2 – 5 lb weight loss. BWRP variables were not significantly related to reported likelihood of changing behaviors to prevent any of the amounts of weight gain, although the variables were significant in the multivariate regression.

<u>Hypothesis 3</u>:

Path analysis was used to test the hypothesis that ratings of importance and difficulty of preventing 6 – 10 lb of weight gain would be related to reported likelihood of changing behaviors to prevent a 6 – 10 lb weight gain (**Figure 4.3**). This 6 – 10 lb weight range was selected because results from the multivariate analysis (Table 4.3) suggested that the BWRP was significantly related to importance and difficulty of weight change, and likelihood of weight loss for this weight range. The figure includes only statistically significant paths, given as probit regression coefficient estimates for categorical outcomes. Model fit statistics indicated acceptable fit to the data (χ^2 = 24.7, 6 d.f., p = 0.0004, CFI/TLI = 0.97/0.95, RMSEA = 0.10). There was an inverse direct effect of BMI quintiles and satisfaction with CBW on the amount of weight loss desired (CBW – DBW quintiles). Satisfaction with CBW had a positive direct effect on the amount of weight loss desired and an inverse direct effect on ratings of importance of preventing a 6 – 10 lb weight gain. The amount of weight loss desired had a positive direct effect on difficulty of preventing a weight gain of 6 – 10 lb. Ratings of importance of preventing a 6 – 10 lb weight gain had a positive direct effect on ratings of likelihood of changing behaviors to prevent a 6 – 10 lb weight gain. Difficulty of preventing a 6 – 10 lb weight gain had a negative direct effect on likelihood of changing behaviors to produce a 6 – 10 lb weight gain. The estimated total effect of BMI with likelihood of changing behavior to prevent weight gain was estimated to be 0.05 $\pm$ 0.04 (p = 0.14). The estimated total effect (direct and indirect) of satisfaction with CBW with likelihood of changing behaviors to prevent weight gain was estimated to be - 0.09 $\pm$ 0.03 (p = 0.002).

Path analysis was also used to test the hypothesis that ratings of importance and difficulty of producing a 6 – 10 lb weight loss would be related to reported likelihood of changing behaviors to produce a 6 – 10 lb weight loss (**Figure 4.4**). Model fit statistics indicated good fit to the data (χ^2 = 7.0, 6 d.f., p = 0.35 CFI/TLI = 0.999/0.999, RMSEA = 0.02). As in the previous model describing prevention of weight gain, BMI had a positive direct effect on the amount of desired weight loss. The amount of desired weight loss, in turn, had a positive direct effect on ratings of importance of a 6 – 10 lb

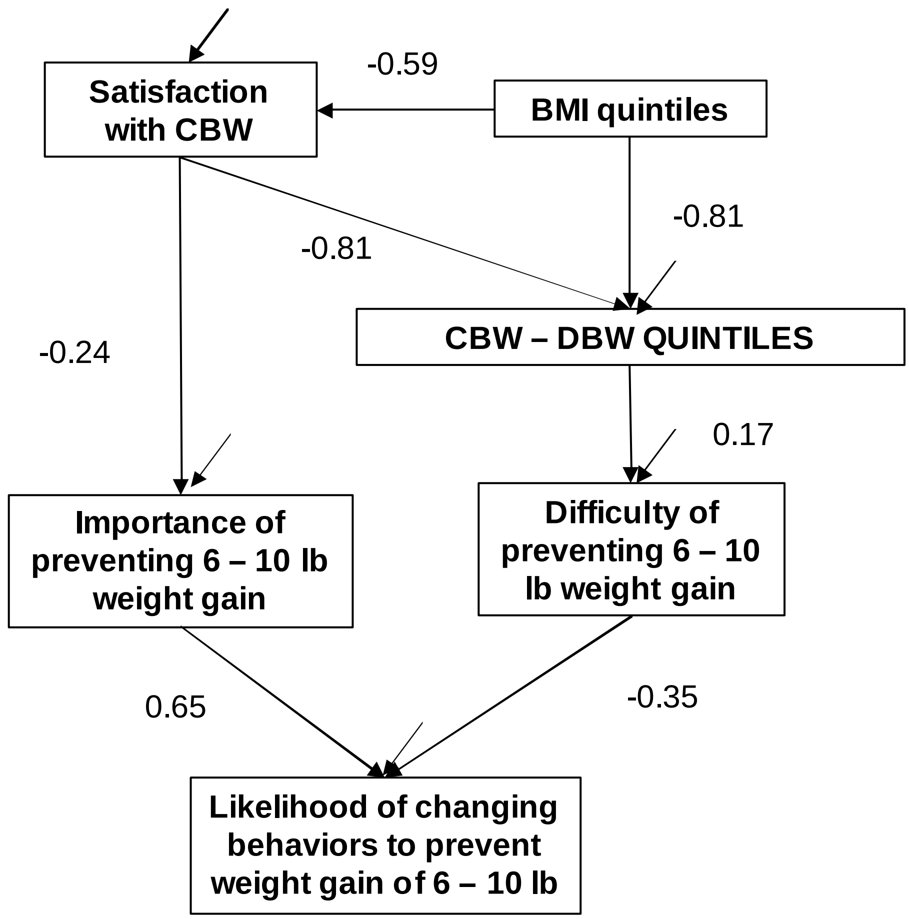


Figure 4.3. Probit regression coefficient estimates for relationships between body size, importance, difficulty and likelihood of changing behaviors to prevent weight gain of 6 – 10 lb. All estimates are significant at $p < 0.0001$

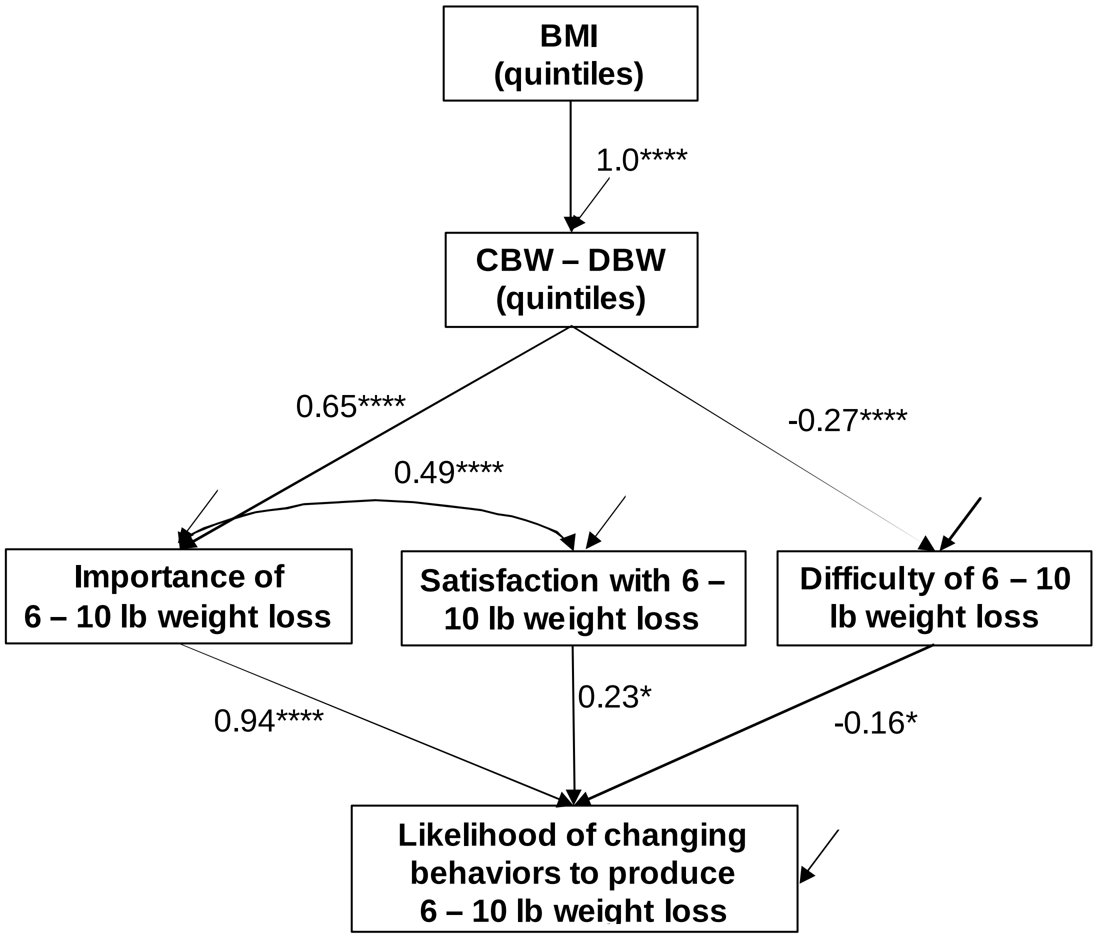


Figure 4.4. Probit regression coefficient estimates for relationships between body size, satisfaction with current body weight, importance, difficulty and likelihood of changing behaviors to produce weight loss of 6 – 10 lb.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

weight loss, and had an inverse direct effect on ratings of difficulty of producing a 6 – 10 lb weight loss. There was a positive association between importance and satisfaction with a 6 – 10 lb weight loss. Ratings of importance and satisfaction with a 6 – 10 lb weight loss both had positive direct effects on likelihood of changing behaviors to produce a 6 – 10 lb weight loss. Ratings of difficulty of producing a 6 – 10 lb weight loss had an inverse direct effect on likelihood of changing behaviors to produce a 6 – 10 lb weight loss. The path models explained 9% - 80% of the total variance of the dependent variables (**Table 4.4**). This evidence supports the hypothesis that ratings of importance and difficulty would influence reported likelihood of changing behaviors to produce weight change.

Table 4.4. R^2 estimates from path models predicting likelihood of changing behaviors to produce weight change of 6 – 10 lb.

	Model	
Dependent variable	Weight gain	Weight loss
CBW – DBW quintiles	0.80	0.63
Importance of weight change	0.09	0.54
Difficulty of weight change	0.12	0.16
Likelihood of changing behaviors to produce weight change	0.36	0.74
Satisfaction with CBW	0.41	--

Discussion

To the author's knowledge, the relevance of the reference point concept derived from Prospect Theory has not been considered in understanding how individuals conceptualize specific amounts of weight change. Previous research has incorporated aspects of Prospect Theory into examining implications for the framing of health behavior messages as either gain- or loss-oriented (12-15), and to develop an incentive-based approach to encourage weight loss (16). Some studies found that both loss- and gain-framed health behavior messages were effective in increasing and improving target behaviors (12-15). Another study found no effect of positive or negative framing on measures of cognitive processing regarding the target behavior (13). One randomized controlled trial found that subjects who were given either positive or negative financial incentives to lose weight had significantly greater weight loss than those given no financial incentive (16). The results of the current study demonstrate the importance of an individual's current body weight status ("body weight reference point", BWRP) in how individuals operationalize subjective values regarding the importance, difficulty, and likelihood of changing behaviors to produce weight change.

Outcome expectancies and the valuation of those expectations are essential components to many of the health behavior theories most commonly applied in the literature, such as the Health Belief Model, the Transtheoretical Model, the Theory of Reasoned Action/Planned Behavior, and Social Cognitive Theory. The findings of the present study extend the theoretical framework for decisions regarding weight-related nutrition and exercise behaviors by providing insights into how individuals operationalize the value of expected weight change outcomes. The results of the present study suggest that this valuation is influenced both by whether the outcome will improve or worsen the status quo, as well as by an individual's BWRP (current body size as defined by BMI and the difference between current and desired body weight). Further, these results provide evidence in support of the prediction of behavioral economics and health behavior theories that an individual will be more likely to engage in a behavior if the perceived benefits (importance) of the outcome are high and the perceived burdens (difficulty) of changing behaviors are low (3, 17-19).

Hypothesis 1: Ratings of importance of preventing weight gain were higher than those for producing weight loss, except for the 2-5 lb weight range. Women reported higher ratings of difficulty of losing weight compared with that of preventing weight gain above the 2 – 5 lb range (there were no differences between ratings of difficulty of preventing or losing 2 – 5 lb). Reported likelihood of changing behavior to prevent weight gain was higher than that of losing weight, except for the 2 – 5 lb range, for which the opposite was true. This evidence supports the predictions of Prospect Theory for weight ranges above 2 – 5 lb. In this study sample, the importance of preventing, and the likelihood of changing behaviors to prevent, a small weight gain (2-5 lb) was rated lower than that of larger amounts of weight gain, and there was no difference between ratings of difficulty for this range. These results suggest a potential opportunity for behavioral interventions to attempt to increase the perceived value of the expected outcome of small amounts of weight gain in order to prevent incremental gains that have been reported to occur throughout adulthood (20, 21).

Hypothesis 2: The study results support the hypothesis that the BWRP is related to ratings of importance, difficulty and likelihood of changing behavior to produce all amounts of weight change. Overweight and obese women, and women with current body weight at least 25 lb above their desired body weight, reported overall higher ratings of importance of weight change and likelihood of using strategies to produce weight change than normal weight women and women within 25 lb of their desired body weight. Overweight and obese women, and women with current body weight $\geq$ 25 lb above their desired body weight, reported overall higher ratings of difficulty of preventing weight gain, but lower ratings of difficulty of producing weight loss compared with normal weight women and women < 25 lb above their desired body weight. To the author's knowledge, the possibility that outcome expectancies regarding weight change may vary according to an individual's current body size has not yet been considered in the literature. These results suggest that increasing the valuation of a weight gain for women who are still of normal weight and close to their desired body weight may be a useful target for behavioral interventions.

Hypothesis 3: These findings support the hypothesis that ratings of importance and difficulty of producing weight change are related to reported likelihood of changing behaviors to produce weight change. Different constructs were shown to influence ratings of likelihood of changing behaviors to prevent weight gain versus likelihood of changing behaviors to produce a weight loss. Both models indicated a positive indirect association of BMI with likelihood of changing behaviors to prevent weight gain and produce weight loss. In addition, results from the path analysis for the model predicting likelihood of changing behaviors to prevent a 6 – 10 lb weight gain showed that ratings of likelihood of changing behaviors to prevent weight gain were positively influenced by ratings of importance (perceived value of expected outcome) of weight gain, and negatively influenced by ratings of difficulty (perceived burdens) of preventing weight gain, which were both in the hypothesized direction. Further, the path analysis for the model predicting likelihood of using behaviors to produce a 6 – 10 lb weight loss demonstrated that ratings of the subjective value of the expected outcome (importance and satisfaction) were positively related to ratings of likelihood of changing behaviors to lose weight, while ratings of the subjective cost (difficulty) of changing behaviors were negatively associated with ratings of likelihood of changing behaviors. These results support the prediction of behavioral economics and health behavior theories that reported likelihood of changing behaviors to produce weight change is positively related to the perceived value of the expected outcome and inversely related to the perceived costs associated with the expected outcome.

<u>Inconsistencies with Prospect Theory</u>: The results given in Figure 4.2 indicate some important differences between the current findings and the predictions of Prospect Theory as illustrated in Figure 4.1 (see **Appendix B** for an alternative presentation of these findings). First, whereas the pattern of perceived importance of weight gain resembles the expected pattern of value function of a negative outcome demonstrated in Figure 4.1 (the importance of preventing weight gain increases at a decreasing rate as weight gain increases), the pattern of perceived importance of weight loss does not reflect the expected value function of a positive outcome (the importance of losing weight decreases as weight loss increases). This is likely to be because weight loss would be expected to have increasing subjective value only up to an individual's desired body weight, and then be expected to decrease (or plateau and then decrease). This explanation also applies to the findings regarding reported likelihood of changing behaviors to produce weight change

(Appendix B). The survey conducted for this analysis was not equipped to measure the importance of weight change or likelihood of changing behaviors to produce weight change with enough precision to detect this possibility, which should be a subject for further research.

Limitations

This study is subject to several limitations. First, due to the characteristics of the sample, these results may not be generalizable to populations in other geographic regions, those with different educational backgrounds, or to males. In addition, the response rate for the survey was fairly low, with just over 25% participation. Therefore, the subjects may not be representative of the source population. It was established that the racial diversity of the sample is similar to that of the source population (17% and 15%, respectively), but data on the other demographic characteristics of the source population are not available. It may be that respondents are more interested in weight change or health behaviors than those who refused to participate, which may contribute to higher ratings of importance, difficulty and likelihood of changing behaviors to produce weight change. As a result, the subjective ratings reported in this study may be higher than those that would be reported by a more representative sample, although this would not be expected to bias the validity of the results of the comparisons of within-subject ratings for different directions of weight change, or the relationship between these ratings and the reference point definitions. Replication of these findings in other populations is necessary to verify these results.

Despite the assumptions of causality used in path analysis, the results of this cross-sectional survey cannot be interpreted to suggest a direction of association or causality. Although it was hypothesized that the current BWRP determines ratings of importance, difficulty and likelihood of changing behaviors to prevent weight gain or lose weight, it is possible that the reverse is true, or that there is a bidirectional association. In addition, the present study assessed reported likelihood of changing behaviors, but did not have a measure of actual behavior. While some evidence supports the predictions of health behavior theories (e.g., Theory of Reasoned Action/Planned Behavior, The Transtheoretical Model, and Social Cognitive Theory) that actual behavior proceeds from behavioral intentions (22-24), considerable discrepancy between intentions and actual behavior has been reported in the literature (25-28). Further research is necessary in order to determine whether ratings of subjective importance and difficulty of weight change is related to actual weight-related eating and exercise behaviors.

Despite these limitations, these results suggest that an individual's subjective valuation of the importance and difficulty of producing weight change, and self-reported likelihood of changing behaviors to produce weight change, vary with respect to the BWRP, and with the direction of the proposed weight change. These variables should be considered in future research of health behavior theories and in the development of behavioral interventions to address weight-related behaviors.

APPENDICES

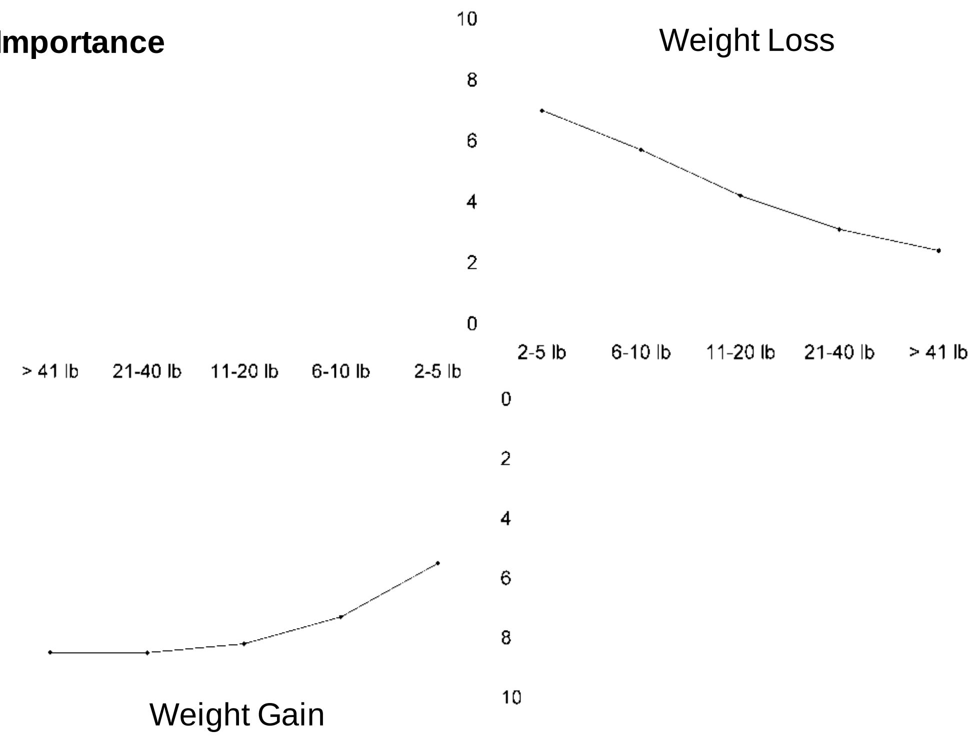
Appendix A. Wording of survey questions regarding importance, difficulty and likelihood of changing behaviors to produce weight change.

Item category and wording	*Response categories*[1]
How important is it to you to prevent the following amounts of weight gain? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb e. 41lb or more	1- not at all important, 5 – somewhat important, 9 – very important
How important is it to you to produce the following amounts of weight loss? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb e. 41lb or more	1- not at all important, 5 – somewhat important, 9 – very important
How difficult would it be for you to prevent the following amounts of weight gain? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb e. 41lb or more	1- not at all difficult, 5 – somewhat difficult, 9 – very difficult
How difficult would it be for you to produce the following amounts of weight loss? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb e. 41lb or more	1- not at all difficult, 5 – somewhat difficult, 9 – very difficult
How likely are you to change your current eating or physical activity strategies in order to prevent the following amounts of weight gain? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb	1- not at all likely, 5 – somewhat likely, 9 – very likely
How likely are you to change your current eating or physical activity strategies in order to produce the following amounts of weight gain? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb	1- not at all likely, 5 – somewhat likely, 9 – very likely
How satisfied would you be if you reduced your current body weight by each of the following amounts? a. 2 – 5 lb b. 6 – 10 lb c. 11 – 20 lb d. 21 – 40 lb	1- not at all satisfied, 5 – somewhat satisfied, 9 – very satisfied

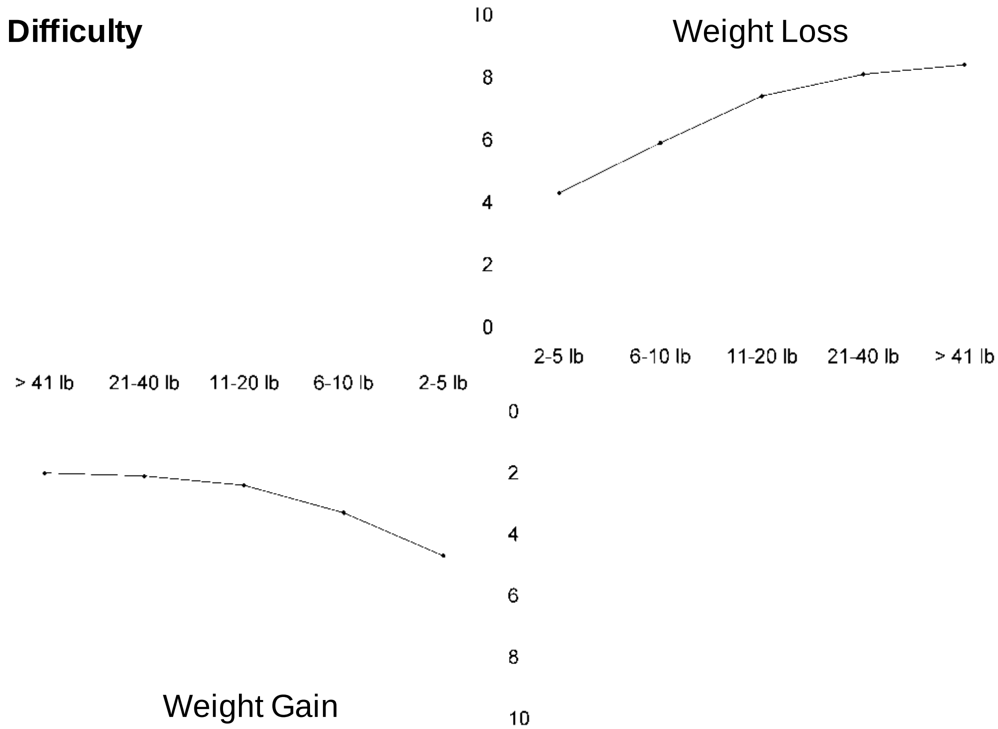
[1]All response options ranged 1 – 9.

Appendix B. Alternative presentation of ratings of the perceived importance (A) of weight gain and weight loss of specified ranges, perceived difficulty (B) of weight gain and weight loss of specified ranges, and reported likelihood (C) of changing behaviors to prevent weight gain and lose weight of specified ranges. All ratings were on a scale of 1 – 9.

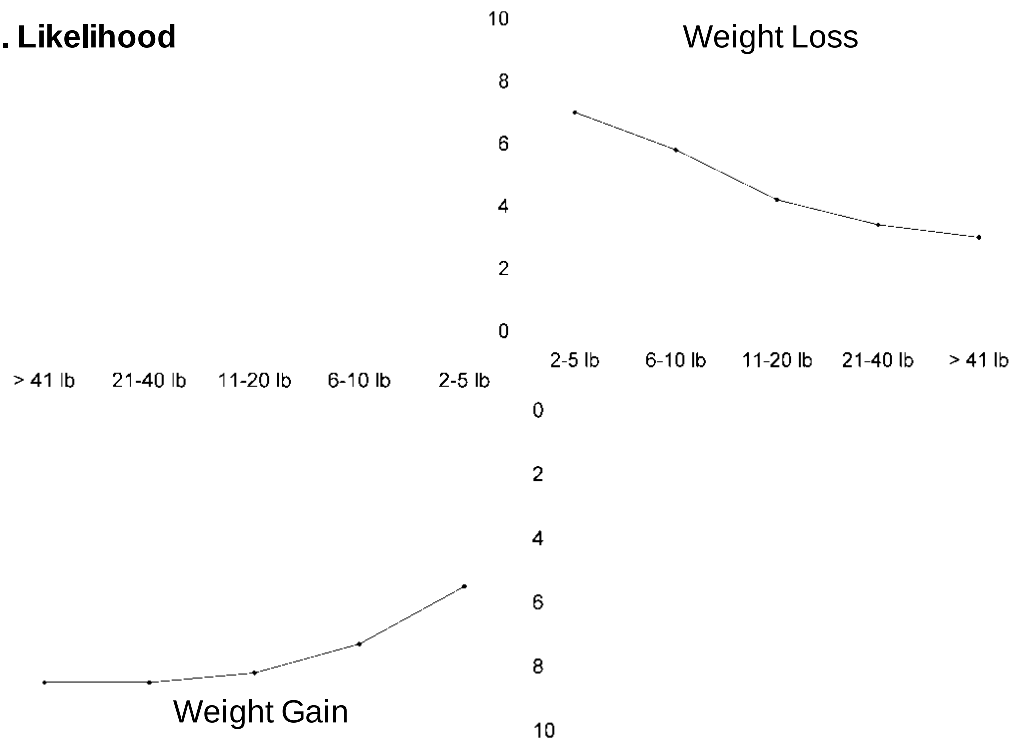
A. Importance



B. Difficulty



C. Likelihood



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CHAPTER 5

CONCLUSION

The studies reported here have investigated changes in maternal body weight between 1YPP and 2YPP and health behaviors at 2YPP, and explored potential applications of Prospect Theory to the theoretical framework for how women conceptualize weight change. This chapter summarizes the key findings and overall significance of this research, and suggests implications for further action and study.

Summary of findings and overall significance

Trends in maternal body weight between 1YPP and 2YPP

The first study examined the natural history of maternal body weight between 1YPP and 2YPP in a sample of subjects enrolled in a prospective cohort study of healthy women receiving prenatal care in 10 counties in upstate New York, U.S. Results showed that weight change between 1YPP and 2YPP was highly variable (min = -24.3 kg, max = 22.0 kg), but with an average of approximately zero, and more than half of the women (N = 211, 54%) in the sample gaining weight in this period. Weight gain was less common among women with high 1YWR. Major weight retention ($\geq$ 4.55 kg) at 1YPP and 2YPP, and risk of moving to a higher risk BMI category, occurred for a minority of women in this study population, and were more likely to occur in women with GWG in excess of the IOM guidelines[4]. Likelihood of returning to EPW or

[4] Since only 35 women (8.5%) in the sample moved to a higher risk BMI category in this study, inferences about this small group should be made cautiously.

below by 2YPP was inversely related to having GWG in excess of the IOM guidelines, and to 1YWR, which mediated the relationships between GWG and postpartum body weight outcomes. Overall, these findings suggest that between 1YPP and 2YPP, women who are still above EPW at 1YPP continue to trend down towards their EPW, although this may not be achieved by the end of the second year postpartum. In addition, although more than half of the women in this population reached EPW or below at either 1 or 2YPP, many women gain weight between 1YPP and 2YPP, such that fewer than half (42%) were at or below EPW at the 2YPP measurement.

This is among the first studies to attempt to distinguish postpartum weight retention from postpartum weight gain. In the majority of previous studies of the relationship between GWG and PPWR, the outcome variable was calculated as the difference between body weight at a given time postpartum and pre-pregnancy body weight. Postpartum weight gain can only be assessed through multiple body weight measurements through an extended period after delivery (at least 12 months), which has been carried out to varying degrees in only a few studies (1-4). In the present study, weight gain between 1YPP and 2YPP was common (N = 211, 54%). If such gain is as prevalent in other populations, studies that do not account for this gain will overestimate retention in many women, and thus overestimate importance of child bearing on maternal obesity development. The postpartum weight gain shown in this study may be the result of lifestyle changes associated with child-rearing, and may help to explain some of the association between parity and body weight reported in the literature (5, 6).

Psychosocial correlates of postpartum health behaviors and weight change

The second study, which examined the same sample as the first study, revealed significant relationships between prenatal psychosocial factors and postpartum health behaviors and weight change. Prenatal LOC and SE were associated with increased postpartum fruit and vegetable intake and exercise frequency. Additionally, SE was directly related to decreased 1YWR and indirectly related to decreased postpartum weight change and increased likelihood of returning to EPW. A consistent association of postpartum health behaviors with PPWC was not suggested in these data. The self-reported measures of these behaviors, and the concurrent measure of these variables with weight outcomes, may contribute to the lack of a significant relationship. In addition, health behaviors and weight change are affected by a large number of personal, biological and environmental factors, and thus the explanatory power of any one variable is likely to be small. The findings from this study regarding the influence of prenatal internal LOC on postpartum health behaviors, and the significant relationship between SE and postpartum health behaviors and weight change have not been shown previously in the literature. A small but significant relationship between these constructs as measured prenatally on postpartum health behavior and weight change suggests an opportunity to target interventions to encourage health behaviors and returning to pre-pregnancy weight after delivery towards those women with low weight-related SE and LOC during pregnancy.

Applications of Prospect Theory to individuals' conceptualization of weight change

The third study, which used results from an online survey of women of reproductive age on a university campus, revealed the relevance of Prospect Theory to individuals' conceptualization of weight change. The survey assessed perceived valuation of expected outcomes ("importance"), perceived cost of behaviors to produce these outcomes ("difficulty"), and behavioral intent ("likelihood of changing behaviors" to produce weight change). A range of methodologies has been implemented in the literature to obtain a measure of individuals' valuation of expected outcomes. For example, one study asked individuals to indicate their willingness to risk death to achieve weight loss after bariatric surgery (7). Another study asked respondents to indicate their preference between two different body weight outcomes (e.g., between living for a number of years weighing a number of pounds more, or living for a different number of years weighing a different number of pounds more) (8). The approach used in the current study, to assess perceived ratings regarding specific amounts of weight change, has not been implemented previously in the literature.

Results from the study of the relevance of Prospect Theory to conceptualization of weight change showed that preventing weight gain above the 2 – 5 lb range was perceived of as less important and less difficult than losing an equivalent amount of weight, although preventing 2 – 5 lb of weight gain was perceived of as less important and about the same degree of difficulty as losing 2 – 5 lb. Women also reported being less likely to change behaviors to prevent 2 – 5 lb of weight gain than to lose 2 – 5 lb, and being more likely to change behaviors to prevent greater amounts of weight gain than greater amounts of weight loss.

The results further revealed a consistent association of an individual's BWRP with her subjective ratings of importance and difficulty of weight change, and with reported likelihood of changing behaviors to produce specified amounts of weight change. Women with high BMI and whose current body weight (CBW) was more than 25 lb above desired body weight (DBW) report higher importance and difficulty of preventing weight gain. Ratings of likelihood of changing behavior to prevent all amounts of weight gain were statistically higher for women with high BMI and CBW – DBW > 25 lb (11.4 kg) ($p < 0.05$), although the magnitude of the differences was small ($\leq$ 0.5 on a 9 – point scale), and there were no significant differences among comparisons of individual amounts of weight gain. BMI and CBW – DBW were positively related overall to ratings of importance, inversely related overall to ratings of difficulty of amounts of weight loss, and positively related overall to likelihood of changing behaviors to lose weight. Comparisons for individual amounts suggested this difference was more pronounced for weight loss greater than the 2 – 5 lb range. These results indicate that the reported increased likelihood of changing behaviors to lose weight (especially large amounts) is considerably more prominent than the reported increased likelihood of changing behaviors to prevent weight gain according to BMI and CBW – DBW.

Results from this study demonstrated a significant positive relationship between ratings of importance (subjective value) and likelihood of changing behaviors to prevent a weight gain of 6 – 10 lb, and a negative relationship between ratings of difficulty (subjective cost) and likelihood of changing behaviors. Similarly, likelihood of changing behaviors to lose 6 – 10 lb was positively related to ratings of importance and satisfaction with a 6 – 10 lb weight loss, and inversely related to ratings of difficulty of losing 6 – 10 lb. These results support the predictions of several health behavior theories about the relationship between behavioral decisions and perceived benefits and costs.

The finding that women who are further from their DBW report greater importance, lower difficulty, and greater likelihood of changing behaviors to produce weight loss, may offer some insights into why, in the first two studies, weight loss was positively related to 1YWR. If mothers are assumed to perceive their pre-pregnancy weight as their “desired body weight”, then EPW may correspond closely to DBW, and 1YWR would correspond to CBW – DBW. Thus, greater 1YWR would be predicted to lead to increased likelihood of changing behaviors to lose weight and prevent weight gain, although findings from the second study did not suggest a consistent relationship between 1YWR and late postpartum health behaviors. This may be because SE and internal LOC were associated with reduced 1YWR and increased exercise frequency and fruit and vegetable intake at 2YPP. Thus, women with greater 1YWR have lower SE and more external LOC than women with less 1YWR, and would be expected to be less likely to perform weight-control behaviors. In addition, the inverse association between the BWRP and likelihood of changing behaviors to prevent weight gain revealed in the third study may explain why women in the first two studies who had less weight retention at 1YPP were more likely to gain weight in the following year than those with more weight retention at 1YPP.

Implications for future research and overall significance

Although moving to a higher risk BMI category in the first study was rare in the study sample, this risk was increased in women with GWG above the IOM guidelines. In addition, high GWG was related to reduced likelihood of returning to EPW. Thus, women may retain excess weight accrued during pregnancy for at least 2 years postpartum. However, weight loss between 1YPP to 2YPP is more common among women who are still above EPW at 1YPP. Further research of maternal body weight after 2YPP is necessary to determine the long-term weight trajectory of women with large GWG. More data collection on breastfeeding behavior may help to explain some of the variation in late postpartum body weight change. In addition, more frequent measures of maternal body weight in the postpartum period are necessary to characterize postpartum maternal body weight trends further. The finding that a majority of the sample gained weight between 1YPP and 2YPP suggests that future studies of postpartum weight retention should account for postpartum weight gain to prevent overestimation of the contribution of GWG to long-term increases in maternal BMI.

The results regarding the relationship between prenatal psychosocial measures and postpartum health behaviors and weight change indicate that these measures may help health providers to identify women during prenatal care who may be predicted to struggle to return to pre-pregnancy weight in the postpartum period. Such information may help providers to implement behavioral interventions during pregnancy, when many women are more receptive to these changes than they may be at other stages in the life course (9-15). Future research may explore the efficacy and effectiveness of targeting delivery of interventions to women who are identified during pregnancy as having low self-efficacy and external locus of control. Potential intervention goals may include promoting GWG within the IOM guidelines, and encouraging the continuation or adoption of healthy eating and exercise behaviors after delivery through nutrition education and exercises to enhance SE and internalize LOC.

If 1YWR is interpreted as the difference between current and desired body weight, the results from the third study suggest that greater 1YWR would be related to greater perceived importance, lower perceived difficulty, and greater likelihood of changing behaviors to produce weight loss in order to achieve EPW, which would lead to increased weight loss after 1YPP. For women who are at or close to 1YPP, delivery of interventions that put greater emphasis on the importance of preventing small amounts of weight gain may be effective at preventing postpartum weight gain. In the first study, among women who gained weight between 1YPP and 2YPP, average weight gain was 3.1 ± 3.0 kg, which, in the third study, falls within the range of what was perceived of as very important and not very difficult. Replication of these findings in more representative populations may suggest a need for programs that promote prevention of small amounts of weight gain, especially in women with BMI in the normal weight range, and for mothers who are close to or below EPW after delivery. Other targets of such programs may include emphasis on increasing perceived importance (subjective value) and of reducing perceived difficulty (subjective costs) of preventing small amounts of weight gain. Further research should explore a variety of methods for increasing the perspective value reducing the real and perceived costs associated with weight-control behaviors and outcomes.

This research contributes to the extant literature by providing new evidence regarding the progression of maternal body weight after 1YPP, and by enhancing understanding of how women conceptualize weight change outcomes. Key findings were, first, that postpartum weight gain is common after 1YPP. Importantly, although it is reasonable to expect that women who gain weight during this period may be the same women who gain excessively during pregnancy and fail to return to pre-pregnancy weight in the first year after delivery, the findings presented here indicate that this is not the case. Rather, women with low weight retention at 1 year postpartum are far more likely to gain weight after this period than are women with high weight retention at 1 year postpartum. The second key finding was that psychosocial factors assessed during pregnancy are related in the expected direction to eating and exercise behaviors assessed at 2 years postpartum and to maternal body weight from 1 to 2 years postpartum. This information may help clinicians to identify women during pregnancy who are more likely to benefit from programs that encourage healthy postpartum behaviors and body weight outcomes. The third key finding was that women's conceptualization of weight change outcomes is dependent on her current body weight status, referred to as the body weight reference point (BWRP). Thus, the perceived value and difficulty of losing a certain amount of weight or preventing a certain amount of weight gain is not the same for women of all body sizes. In addition, women report low perceived importance of preventing small amounts of weight gain relative to other body weight outcomes. Since body weight increases gradually for many adults, this finding suggests an opportunity to promote the importance of preventing small amounts of weight gain to decrease the incidence of overweight and obesity.

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